METAL PROGRESS

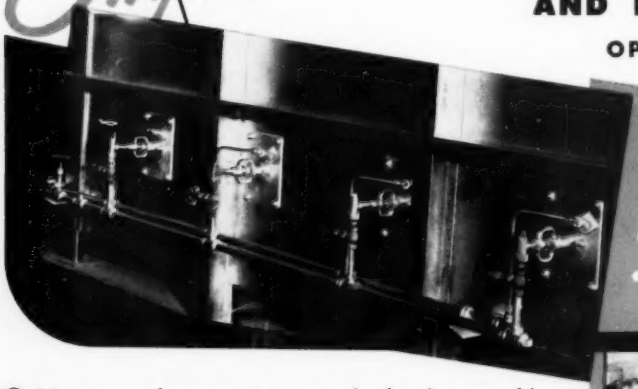
CUT COSTS!

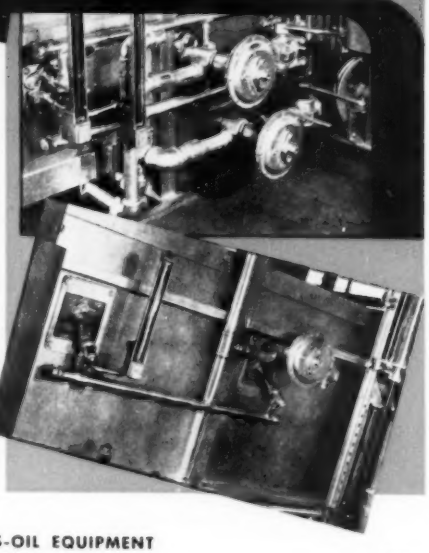
Improve Furnace Operation!

'SURFACE' GAS BURNERS AND BURNER EQUIPMENT

OPERATE ECONOMICALLY ON EXISTING FURNACES BY GIVING:

- Reduced Fuel Costs
- Reduced Number of Rejects
- Uniformity of Quality
- Accurate Temperature Control
- Lower Production Costs





● Many manufacturers pay a penalty by the use of inefficient combustion equipment, when the installation of modern 'Surface' Gas Burners and Burner Equipment could effect many economies.

During the many years of 'Surface' Gas Burner engineering, manufacturing and installation on existing furnaces, there have resulted additional operating dividends for the user.

Proper selection, sizing and installation of burner equipment are important factors in greater overall operating economies. Ask an experienced 'Surface' Combustion Engineer to investigate possibilities of improvement of your furnace equipment.

A Choice of OVER 60 TYPES—600 SIZES

	SPECIFICATION SHEET NO.
BURNER-INSPIRATOR UNITS	
Low Pressure Velocity Burners	2VL-8
Variable Flame Burners	2VF-8
High Pressure Velocity Burners—"VLT"	2VH-8
Webster Series VI Burners	2VW-8
BURNER NOZZLES	
Tunnel Burners	2BT-8
Flame Retention Tip Burners	2BF-8
Continuous Line Burners	2BL-8
Lava Tip Burners	2BR-8
INSPIRATORS	
Low Pressure Inspirators	2PL-8
High Pressure Inspirators	2PH-8
TUBULAR HEATING EQUIPMENT	
Radiant Tube Heating Elements	2TR-8
Suction Immersion Equipment	2TS-8
Atmospheric Immersion Burners	2TA-8
GAS-OIL EQUIPMENT	
Gas-Oil Burner	2ML-8
Oil Standby	SC-139
ATMOSPHERIC	
Ring Burners and Pipe Burners	2AP-8
Tile Burners	2AB-8
Torch Burners	2AT-8
Air Mixers, Venturi Mixers and Cocks	2AM-8

Write for Specification Sheets on Burner Equipment of your particular interest.

SURFACE COMBUSTION CORPORATION, TOLEDO 1, OHIO

'Surface' STANDARD RATED

INDUSTRIAL FURNACES AND BURNERS

BRAZED AND HARDENED AT THE *Same* TIME

ONE EVERY *20 Seconds!*

with TOCCO* Induction Heating

Your product may be very different from the Kennametal coal-cutting bit shown here, but if you have to harden, braze, anneal or forge it, TOCCO can probably improve your product, speed your production and cut your costs.

Engineers at Kennametal, Inc., Latrobe, Pa., have hit upon a thrifty production shortcut that saves time and expense and improves their product, too. The mining-machine bit is heated to 1600° F, brazing the carbide insert to the steel shank. The cutter is then quenched, hardening the alloy steel shank to 47-52 R.C. Result: a super-tough cutter that will stand the most rugged production tests with a carbide tip that's on for life.

Besides combining the hardening and brazing operations TOCCO has stepped up production to the rate of one part every 20 seconds—nearly twice the production obtained by former methods—with a consequent reduction of unit costs.

TOCCO engineers are ready to survey your operations to find where TOCCO Induction Heating can help you improve your products, speed your production and reduce your costs.

THE OHIO CRANKSHAFT COMPANY

TOCCO

Mail Coupon Today

NEW FREE BULLETIN

THE OHIO CRANKSHAFT CO.
Dept. R-3, Cleveland 1, Ohio

Please send copy of "Typical Results of TOCCO Induction Hardening and Brazing".

Name _____
Position _____
Company _____
Address _____
City _____ Zone ____ State ____

LOOKING FOR...

CHASE is at your service to supply you with a great variety of free-cutting brass and bronze alloys in round, hexagonal, and octagonal rod; square or rectangular bar, and many shapes.

Chase rod alloys are extruded and cold drawn to finished dimensions... are uniform in composition and structure... and made to close dimensional tolerances. Our regular alloys are available in quite large diameters and long lengths.

In Chase free-cutting brass rod about 9,000,000 lead particles are removed in one revolution of a ¼" drill! Each particle contributes to the ease of machining that results in longer tool life!

Why you should specify CHASE!

1. The largest network of brass and copper warehouses.
2. Chase warehouses mean faster delivery, less idle tool time.
3. Free advisory service in the selection of copper alloys.
4. Because Chase is the nation's headquarters for brass and copper, you can do "one-stop" shopping. Many items needed for assembly work or maintenance, such as bearing bronze and rivets, can be supplied... in addition to raw materials needed for production.

Chase *the Nation's Headquarters for* BRASS & COPPER

WATERBURY 91, CONNECTICUT — SUBSIDIARY OF KENNECOTT COPPER CORPORATION

THIS IS THE CHASE NETWORK... *handiest way to buy brass*

ALBANY† ATLANTA BALTIMORE BOSTON CHICAGO CINCINNATI CLEVELAND DETROIT HOUSTON† INDIANAPOLIS KANSAS CITY, MO. LOS ANGELES MILWAUKEE MINNEAPOLIS NEWARK NEW ORLEANS NEW YORK PHILADELPHIA PITTSBURGH PROVIDENCE ROCHESTER† SAN FRANCISCO SEATTLE ST. LOUIS WATERBURY (†Indicates Sales Office Only)

Improved Surface Qualities For Many Parts and Tools

A new member of the familiar Homo family, the Steam Homo is specifically designed for steam atmosphere heat treatment between 750 F and 1150 F. Typical of the specialized applications of this method are the treatment of —

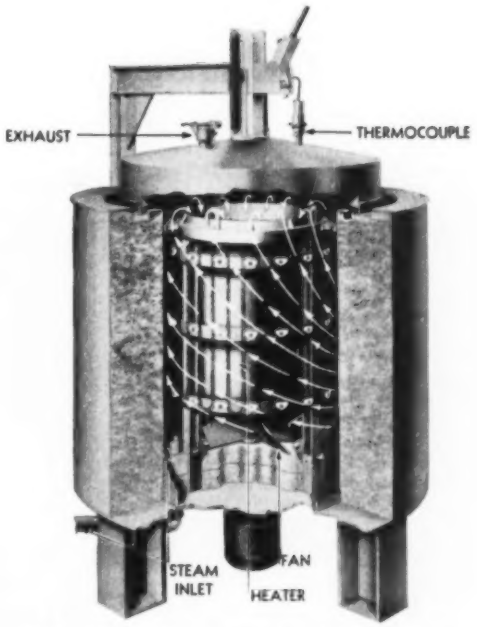
- powdered iron parts . . . for greater hardness, resistance to wear and corrosion
- twist drills and other tools . . . for longer life when cutting hard stock
- copper alloy parts . . . for easier cleaning before plating
- cast iron parts . . . for improved wear resistance
- steel parts . . . for faster, smoother machining and grinding characteristics

The Steam Homo Method combines four outstanding advantages:

(1) Steam atmosphere — for scale-free, blue-oxide finish.

(2) Homo forced-convection circulation — for rapid, uniform heat treatment.

A typical installation, showing milling cutters being loaded into furnace. Furnace Control panel is at right.



Used with or without steam, interchangeably, Steam Homo is adaptable for straight tempering at all usual temperatures, as well as for steam treatment. Driven by a powerful fan, hot steam swirls through the load, heats every piece rapidly and uniformly. Steam from a process line or small generating unit is fed through pipe in bottom of furnace.

(3) Accurate Duration-Adjusting Type of Micromax Electric Control, fully proportioning — holds work at precise temperature.

(4) Micromax Record shows furnace cycles.

Compact and simple to operate, the Steam Homo Furnace handles big loads of small parts quickly and efficiently. It is so clean and quiet that it can even be installed right on the production line. It is a complete, integrated assembly of furnace and control instruments . . . engineered to operate effectively together.

Our Cat. T-625 Sec. I will be sent on request, or, if you have a specific application, an L&N engineer will call. Write to Leeds & Northrup Co., 4927 Stenton Ave., Philadelphia 44, Penna.

MEASURING INSTRUMENTS · TELEMETERS · AUTOMATIC CONTROLS · HEAT-TREATING FURNACES

LEEDS & NORTHRUP CO.

Jrl. Ad T-620 (27)

Metal Progress is published and copyrighted, 1949, by American Society for Metals, 7301 Euclid Avenue, Cleveland, Ohio. Issued monthly; subscriptions $7.50 a year. Entered as second-class matter Feb. 7, 1921, at the post office at Cleveland, Ohio, under the act of March 3, 1879.

AIRCO ANNOUNCES

The Aircomatic Process . . . An entirely new idea for welding aluminum in ALL POSITIONS

Sensational in its conception, Airco's new *Aircomatic Process* introduces an entirely different aluminum fabricating technique to industry. With this process, welding of aluminum and weldable aluminum alloys ranging in thicknesses from $\frac{1}{8}$" to 2" plus, may be performed in all positions – flat, horizontal, vertical and overhead. All of the standard joint designs may be welded in these positions.

Single or multi-layer welds can be deposited using either beading or weaving techniques. Vertical welds may be made with either upward or downward travel. In short, all of the facility associated with metal arc welding of steel is made available by this process, plus the advantages of high deposition rates, far exceeding those attained by usual welding methods, which results from continuous filler metal feed and the absence of slag.

This new welding method consists of feeding a bare filler metal in wire form at speeds ranging from 100 to 300 inches per minute through a manually operated gun. The filler metal carries welding current and an arc is maintained between the end of the wire and the work. Power may be supplied from a standard d.c. welding generator. The arc is maintained within a controlled envelope of shielding gas.

THE ADVANTAGES OF THIS TOTALLY UNIQUE AIRCOMATIC WELDING PROCESS INCLUDE:

- . . . A manual welding process with the essential features of automatic welding.
- . . . Continuous deposition of filler metal at high rates.
- . . . Manual manipulation of an automatic process for welding in a vertical and overhead position.
- . . . High quality weld metal deposits.
- . . . Minimum edge preparation owing to deep penetration.
- . . . Ability to weld heavy sections with little or no preheat.
- . . . No flux required; slag removal eliminated.
- . . . Visible arc; no blind welding.

Investigate the many advantages the new Aircomatic Welding Process *offers you. For equipment, price, service or other pertinent information, call or write our nearest office.*

AIRCO **AIR REDUCTION**

Offices in Principal Cities

Headquarters for Oxygen, Acetylene and Other Gases . . . Carbide . . . Gas Welding and Cutting Machines, Apparatus and Supplies . . . Arc Welders, Electrodes and Accessories

4 EXTRA "INGREDIENTS"

go into TIMKEN® stainless steel forging bars

1. *Leadership in alloy steel research.*
2. *Special methods practical only in a large, flexible, specialty mill.*
3. *Precise quality control from melting through final inspection.*
4. *Specialized experience in fine alloy steels.*

TIMKEN stainless steel forging bars do more than provide the basic requirements of long service life, resistance to corrosion and fatigue. The difference lies in the *uniform* qualities of Timken forging stock—made possible by the "extras" shown above. Because of that uniformity from bar to bar, you get fewer rejects, fewer delays, fewer changes in shop practice. Constant, high quality is assured in finished products.

Timken stainless steel is "tailored" to fit your specifications for chemical and physical properties. Our Technical Staff will be glad to recommend the correct analysis for your individual requirements. Write for 112-page booklet of forging data, "Evaluating the Forgeability of Steels". The Timken Roller Bearing Company, Steel and Tube Division, Canton 6, Ohio. Cable address: "TIMROSCO".

YEARS AHEAD—THROUGH EXPERIENCE AND RESEARCH

Specialists in alloy steel—including hot rolled and cold finished alloy steel bars—a complete range of stainless, graphitic and standard tool analyses—and alloy and stainless seamless steel tubing

this steel "saves its skin" under fire

If your product-problem is a combination of heat and corrosion, ARMCO ALUMINIZED Steel may be the economical metal you are looking for.

This aluminum-coated steel gives your products many desirable properties which *neither steel nor aluminum alone can give you.* It "covers up" under heat by starting to alloy with the aluminum coating at about 900° F.—forming a heat-resistant refractory layer. There is no destructive heat scaling below 1250° F.

RESISTS DISCOLORATION

It has many other advantages too: Resistance to heat discoloration up to 900° F.; high heat reflectivity; resistance to corrosion by various gases at moderately elevated temperatures; plus the rigidity, creep strength and impact resistance of steel.

ARMCO ALUMINIZED Steel withstands moderate drawing and forming operations without damage to the coating. It can also be spun to moderate depths. Most welding methods are satisfactory.

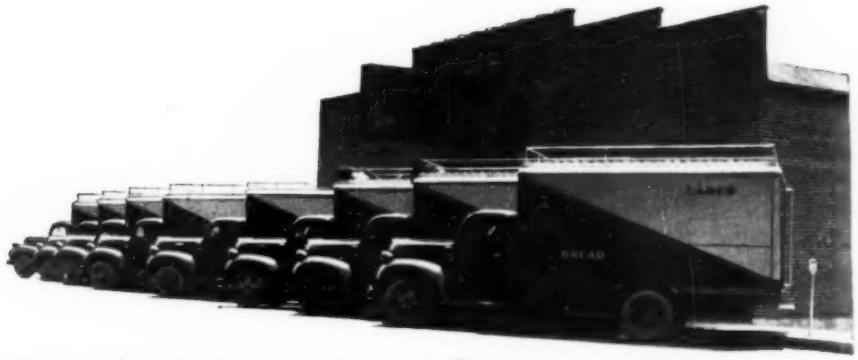
Gage limits are 12 to 30 in sheets or coils. Weight of the aluminum coating is about .5 oz. per square foot of steel, resulting in a coating thickness of about .001" on each side.

Write us for complete information on ARMCO ALUMINIZED Steel. If you wish, our metallurgists will be glad to consult with you about your application. Just address Armco Steel Corporation, 113 Curtis Street, Middletown, Ohio.

Export: The Armco International Corporation

ARMCO ALUMINIZED STEEL

They put the weight where it pays . . . into payload!



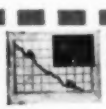
Efficient fleet owners know that there's not a penny of profit in hauling dead weight.

That's why this progressive operator equipped his trucks with magnesium bodies. He put the weight where it really pays off —into payload. With the world's lightest structural metal, body weight was reduced by more than half. The result: greatly increased hauling capacity plus real savings in delivery time, driver fatigue, and truck maintenance. The owner reports a saving of one cent per mile in over-all operating costs.

Here are two more significant facts about magnesium that are often overlooked. It is in inexhaustible supply and prices are more favorable than ever before. Translate these advantages into terms of smoother production and lower costs and you can readily see why more and more truck manufacturers are finding that Magnesium Pays.

DOW
DOWMETAL

Magnesium
IN TRANSPORTATION EQUIPMENT
Pays



Write for the revealing free book "Hauling Costs Down." It's filled with facts about how fleet owners and truck body manufacturers have found that Magnesium Pays.

Send me the study MP-TB-17 "Hauling Costs Down" without obligation.

NAME _____

TITLE _____

FIRM _____

ADDRESS _____

MAGNESIUM DIVISION · THE DOW CHEMICAL COMPANY · MIDLAND, MICHIGAN

New York · Boston · Philadelphia · Washington · Cleveland · Detroit · Chicago · St. Louis · Houston · San Francisco · Los Angeles · Seattle · Dow Chemical of Canada, Limited, Toronto, Canada

HERE IT IS!

and

The

MELTING FURNACE THAT IS REVOLUTIONIZING DIE CASTING!

...THE *LINDBERG-Fisher* 2-CHAMBER MELTING FURNACE

★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★ ★

DOUBLE CHAMBER permits charging cold metal without disturbing temperature conditions in ladling or pouring chamber. This eliminates need for special melting furnaces and handling of hot metal thru the shops.

DOUBLE CHAMBER construction confines impurities in charging chamber—only clean metal is allowed to pass into pouring chamber.

DOUBLE CHAMBER permits melting down in case of freeze up.

AUTOMATIC TEMPERATURE CONTROL is amazingly precise. Metal is held at lowest possible temperature insuring sound castings, long die life and maximum number of shots per hour.

CAST "MARVEX"* LINING, "Like wine it seems to get better as it gets older". We don't know what life to expect—definitely more than a year and probably three or four, and it's as easy to replace as pouring a plaster cast. Furthermore, the channels can be replaced without relining the entire furnace.

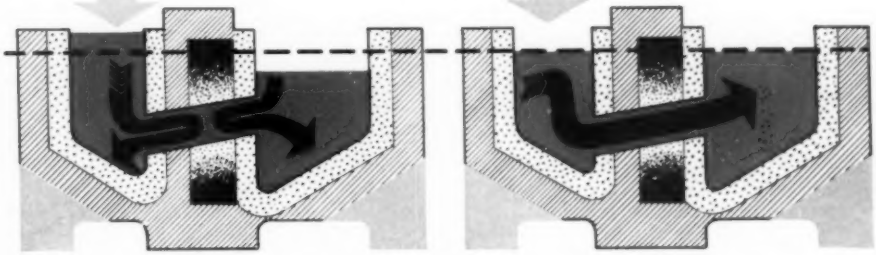
WORKING CONDITIONS are improved immensely which means more production, happier operators.

GENTLE MAGNETIC FLUXING assures clean, homogenious metal.

METAL LOSSES REDUCED to a minimum because the metal is heated from the inside out. Therefore, only coldest part of metal is exposed, and this only to clean, dry air.

**Copyright 1949 Lindberg Engineering Company.*

HERE'S HOW IT WORKS!



POWER ON — Positioning of primary coil in relation to channels forces a greater amount of hot metal into one chamber.

POWER OFF — When power is interrupted, metal flushes thru the channels, cleansing them, as in exaggerated illustrations above.

NEW... PATENTED FEATURES DISCLOSED HERE FOR THE FIRST TIME!

CHANNEL FLUSHING*, *a new development which eliminates the worry of channel clogging.*

The primary coil of the furnace is so positioned in relation to the channels as to cause a greater amount of hot metal to be forced into one chamber than the other. This causes a higher level of metal to exist in the one chamber which is released when power is shut off, resulting in a rush of metal thru the channels to the opposite chamber. When the power is restored, the metal flushes back thru the channels again in the opposite direction. The control equipment includes means for interrupting the power circuit once a minute so the *"Channel Flushing"** occurs twice each minute—once in each direction. The important flushing is the one at the "power off" period when dross and impurities are released from the magnetic field at the "pinch" location.

"CHANNEL FLUSHING"* accomplishes another vital job. By pumping more hot metal into the charging chamber, more BTU's are supplied there to melt the cold metal being charged. It is of course impossible to precisely allocate the exact amount of heat to each of the two chambers *but* the constant flushing of the metal between chambers evens out all irregularities of temperature distribution. Constant mixing and stirring also insures uniform metal analysis and provides desirable fluxing action.

**Patents Pending*

Ask for reprint of magazine article "Two Chamber Induction Furnace Lowers Aluminum Die Casting Cost". The writer of that paper, Mr. Floyd J. Kamin, Kamin Die Casting & Manufacturing Co., received the FIRST PRIZE ($1000.00) in the Industrial Furnace Manufacturers Association contest for the best technical article appearing in a trade publication describing methods to increase production, improve quality and reduce cost by the use of modern industrial furnaces.

LINDBERG-Fisher MELTING FURNACES

A DIVISION OF LINDBERG ENGINEERING COMPANY
2448 West Hubbard Street, Chicago 12, Illinois

6 TYPES in 18 SIZES

HEVI DUTY
COMBUSTION TUBE FURNACES

Hevi Duty High Temperature Combustion Tube Furnace

One or two tubes—for operations to 2300° F. (1260° C)—used for carbon and standard combustions—analysis—checking and calibrations which require temperatures from 1100° to 2300° F. (1260° C.)

Multiple Unit Organic Combustion Furnace

Sections four, eight and twelve inches long—each with separate rheostat control—operations up to 1832° F. (1000° C) —an outstanding achievement for accuracy and ease in operation.

HEVI DUTY Combustion Tube Furnaces

have been standard in most laboratories for over thirty years. The various types provide for all combustion tube furnace operations at temperatures from 1100° F. (592° C.) to 2300° F. (1260° C.). Each type has the exclusive feature of a multiple number of heating units readily replaceable by the user. See your laboratory supply dealer or ask for Bulletins HD-738, 138 and 1236.

Hevi Duty Five Tube Combustion Furnace

For continuous service at high temperatures—to 2000° F. (1093° C.)—not generally used for intermittent work.

Multiple Unit Hinged Combustion Tube Furnace

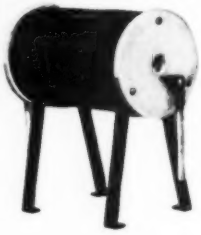
10 standard sizes—for carbon determinations. Special organic analysis and special applications up to 1950° F. (1065° C.)

Multiple Unit Solid Combustion Tube Furnace

10 standard sizes—for carbon determinations and special heat treating operations up to 1950° F. (1065° C.)

Hevi Duty Solid Combustion Tube Furnace

standard sizes—for carbon determination work and other combustion tube furnace operations but constructed for continuous use at higher temperatures to 2000° F.(1093° C.)



The Standard in Most Laboratories

HEVI DUTY ELECTRIC COMPANY

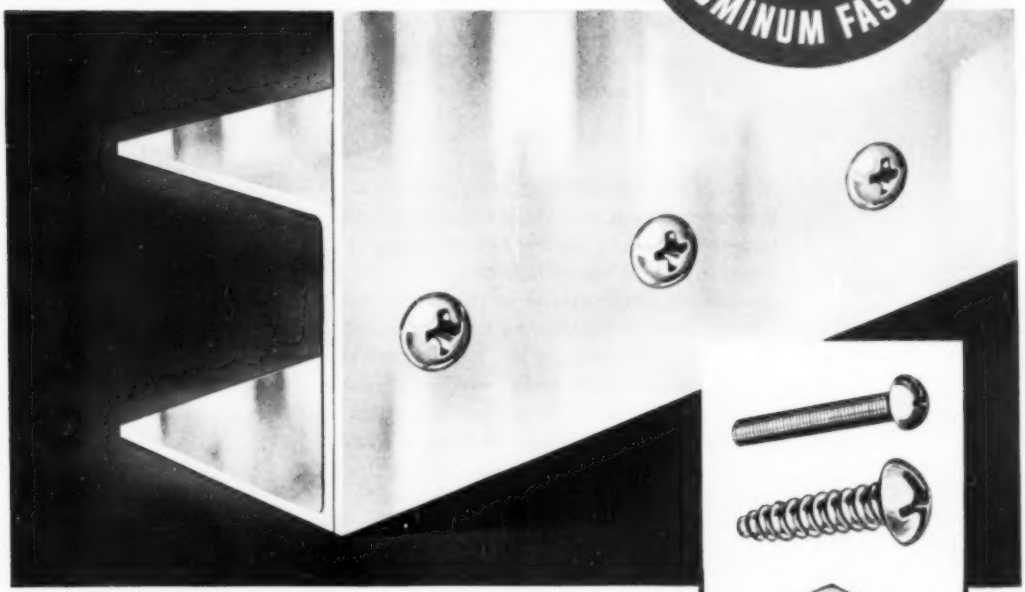
TRADE MARK

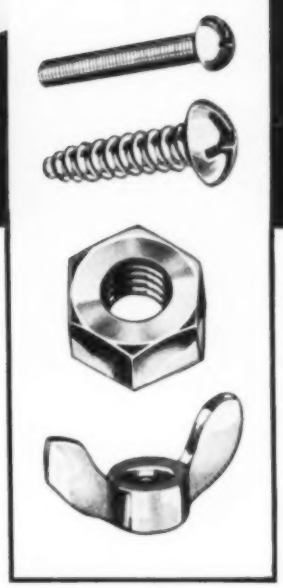
LABORATORY FURNACES **MULTIPLE UNIT** ELECTRIC EXCLUSIVELY

REG. U. S. PAT. OFF.

MILWAUKEE 1, WISCONSIN

THE JOINTS STAY TIGHT WHEN YOU





Use Alcoa Aluminum Sheet Metal Screws

Use of Alcoa Aluminum Fasteners will prevent galvanic corrosion that can result when dissimilar metal screws are used to fasten aluminum assemblies. They help joints stay strong and tight.

Alcoa Fasteners resist common corrosion, too—won't rust red or stain adjacent surfaces. And their low cost will amaze you.

Now available with Phillips heads, for fast, slip-free driving; sheet metal, wood and machine screws, standard sizes and lengths, in all popular head types. Other Alcoa Fasteners, too—hex head bolts, washers, hex nuts, cap nuts, wing nuts, castle nuts, in standard sizes and threads. ALUMINUM COMPANY OF AMERICA, 2101 Gulf Building, Pittsburgh 19, Pennsylvania.

WRITE FOR FREE SAMPLES—Samples of Alcoa Aluminum Fasteners sent free when you request them on your letterhead. Please specify the type and size you'd like.

ALCOA *Aluminum* FASTENERS

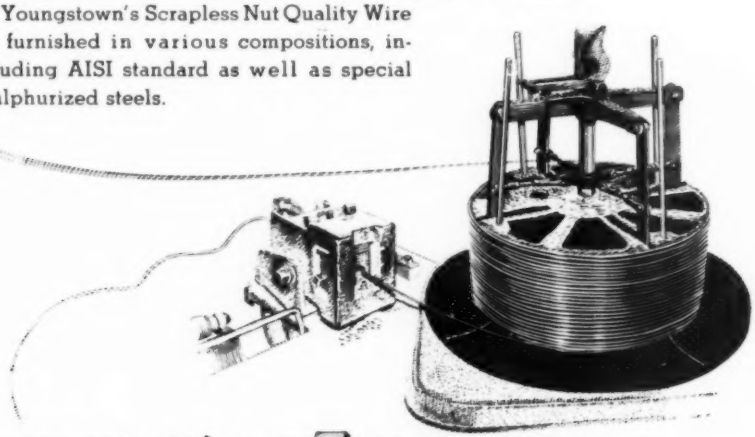
Scrapless Nut Wire

custom built to meet customers' requirements

SCRAPLESS Nut Quality Wire is not an ordinary steel for common applications. It is a custom built product designed to meet customers' specific requirements for cold heading, cold punching, cold expanding and threading, in the production of a variety of nut shapes on continuous heading machines.

Every step of its manufacture is carefully controlled--from the melting furnaces to the final drawing operation on the wire machines. Each coil of wire is subjected to close inspection and rigid tests with modern electrical testing apparatus.

Youngstown's Scrapless Nut Quality Wire is furnished in various compositions, including AISI standard as well as special sulphurized steels.



QUALITY YOUNGSTOWN SERVICE

Youngstown STEEL WIRE

THE YOUNGSTOWN SHEET AND TUBE COMPANY — General Offices — Youngstown 1, Ohio

Manufacturers of Carbon, Alloy and Yoloy Steel — Export Office - 500 Fifth Avenue, New York

WIRE · COLD FINISHED CARBON AND ALLOY BARS · PIPE AND TUBULAR PRODUCTS · CONDUIT · RODS · SHEETS · PLATES · BARS · ELECTROLYTIC TIN PLATE · COKE TIN PLATE · RAILROAD TRACK SPIKES

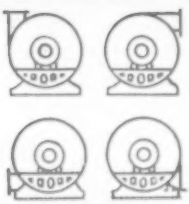
MIDGET: For individual air service the "Midget" is available featuring compactness, light weight and low cost. Built to deliver pressures from 12 oz. to 2 lbs. Motors from ½ to 2 H.P. and volume up to 75 c.f.m. Equipped with universal motors not recommended for continuous service.
BELT DRIVE: For 25 cycle or gasoline engine drive the belt driven unit is offered for continuous service and a large range of capacities, ½ to 50 H.P. and up to 5 lbs. pressure.
SINGLE STAGE: For medium and light duty service, the single stage unit provides efficient and reliable service at low first cost. Pressures from 4 to 16 oz.; capacities from ½ to 20 H.P.
GAS BOOSTER: Gas tight turbos are available in most sizes. Used as gas boosters, and for exhausting acid and poisonous fumes. Non-sparking metals, special packing boxes, overhung or four bearing types, designed for individual requirements.
MULTI-STAGE: For heavy duty service larger capacities and higher pressure. Two types, slow speed 1750 r.p.m. and high speed, 3500 r.p.m. High efficiencies, quiet operation, long life. Capacities up to 20,000 c.f.m. and 5 lbs. pressure.
The multi-stage Turbo-compresser is recommended for all applications requiring the best. Assures long life, low maintenance and reliable service.
4 BEARING: Two types are offered for installations with coupled drive by motors with standard shafts.
Accurate alignment of these blowers is necessary for satisfactory operation, and with the Spencer design this can be easily maintained.
OUTBOARD
OVERHUNG

Spencer centrifugal type Turbo-compressors are regularly used for supplying low pressure air for oil and gas-fired furnaces, foundry cupolas, pneumatic conveyors, agitation of liquids and blowing or exhausting for many different applications. Spencer Turbo-compressors deliver air at varying volumes with a uniform pressure which eliminates the necessity of any adjustment of the blast gate at each change of load.

MECHANICAL ADVANTAGES

Simple Construction	Large Shafts
Lightweight Impellers	Ball Bearings
Wide Clearances	One Piece Casing

Spencer Bulletins are available as follows: **Data Book No. 107, Gas Boosters No. 109, Four-Bearing No. 110, Blast Gates, No. 122, Foundry No. 112. Descriptive Bulletin 127 and Technical Bulletin 126**



The discharge may be in any one of four positions on any Spencer Turbo Compressor.

359-E

SPENCER HARTFORD

THE SPENCER TURBINE COMPANY • HARTFORD 6, CONN.

TURBO-COMPRESSORS

Here's how...

to measure and record displacements from 10 to 10,000 microinches!

"Contour Analyzer" consisting of pickup head, BL-309 Amplifier and Brush Direct-Inking Oscillograph.

The "Contour Analyzer" is an instrument designed to record small displacements from a given reference point or line. Its sensitivity is such that movements as small as 10 microinches can be readily recorded and measured on the chart of the Brush Direct Inking Oscillograph. It can be used in a great number of applications involving small displacements, static or dynamic. Typical uses are as a recording micrometer, vibration recorder, pressure and force recorder, etc. In particular, the instrument lends itself well to the measurement of errors in the contour of irregularly shaped sections.

Specifications

Displacements measurable, 10 to 10,000 microinches	
Frequency Response (overall)	Essentially uniform d-c to 100 cps
Feeler Arm Travel	.015" approximately
Feeler Arm Force	Adjustable
Minimum	approximately 1½ oz.
Amplifier Dimensions	
Length, 17¼" . . . Width, 11" . . . Height, 7½"	
Amplifier Power Requirements	100 watts

Write or call

THE Brush DEVELOPMENT CO.

3405 Perkins Avenue • Cleveland 14, Ohio, U.S.A.

MAGNETIC RECORDING DIV. • ACOUSTIC PRODUCTS DIV.

INDUSTRIAL INSTRUMENTS DIV. • CRYSTAL DIVISION

Canadian Representatives: A. C. Wickman (Canada) Ltd., P. O. Box 9, Station N, Toronto 14

the trend is to N-A-X HIGH-TENSILE STEEL for

BUMPERS • GRILLES • HOODS
FENDERS • BODY PANELS • DECK LIDS
FRAMES • BRACINGS • WHEELS • HUB CAPS
AND OTHER AUTOMOTIVE PARTS

for High Strength • Finer Grain Structure • Good Formability • Great Impact-Toughness • Excellent Weldability
High Corrosion-Resistance • High Fatigue-Resistance

N-A-X HIGH-TENSILE MEETS ALL REQUIREMENTS OF S.A.E. 950

Specify N-A-X HIGH-TENSILE STEEL

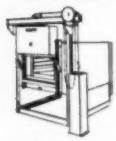
GREAT LAKES STEEL CORPORATION

N-A-X ALLOY DIVISION • DETROIT 18, MICHIGAN
Unit of National Steel Corporation

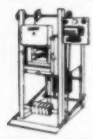
GET UNIFORM DISTRIBUTION OF HEAT

TYPE FR POT FURNACE

TYPE OR-104 POT FURNACE



TYPE FR-251 BOX FURNACE



TYPE FR-206, 207, 208 BOX FURNACE

with Hoskins CHROMEL*—equipped electric furnaces

Good, dependable performance . . . uniform distribution of heat . . . efficient, low-cost operation and maintenance. These are the basic characteristics built into every Hoskins electric furnace. Look at 'em. Their sturdy, rugged construction bespeaks a long and useful life. Check their insulation. You'll find it where it's needed . . . to hold heat in, keep power costs down, assure more comfortable working conditions. Then consider their heating elements. *Durable CHROMEL heating elements!* Designed to give you maximum heating efficiency, long-life trouble-free service. Designed for quick and easy replacement when at last required. Designed from end to end to *fit* the furnace that *fits* your heat treating operations! Our Catalog-59R describes the complete line of Hoskins electric furnaces . . . want a copy?

*CHROMEL . . . the *original* nickel-chrome alloy that *first* made electrical heating practical.

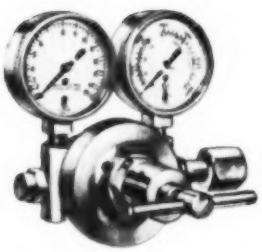
HOSKINS MANUFACTURING COMPANY

4445 LAWTON AVE • DETROIT 8, MICHIGAN

Heating Element Alloys ★ Heat Resistant Alloys ★ Thermocouple Alloys ★ Spark Plug Electrode Wire ★ Special Alloys of Nickel ★ Electric Heat Treating and Laboratory Furnaces

Chromel nickel-chromium wire ®

Take a good look at a 22% saving



Double Gauge Oxygen Welding and Cutting Regulator, made by John Nageldinger & Son, Inc., New York, "Manufacturers of apparatus for the regulating and control of compressed gases since 1880." The cutaway illustration of the regulator is full-scale. All seals in the body are metal-to-metal, no gaskets being used. All parts, excepting the steel spring and nylon valve seat, are copper and copper alloys made by The American Brass Company.

HIGH GAS PRESSURES and sand castings just don't get along together. In fact, when test stand rejects on this job ran as high as 30% at several thousand pounds pressure, something had to be done about it . . . for not only the castings, but all machining operations were a total loss.

The manufacturer consulted The American Brass Company. Dies were made with a few slight changes in design and Anaconda Die Pressed Forgings, made of extruded rod, were supplied as illustrated here and on the following page.

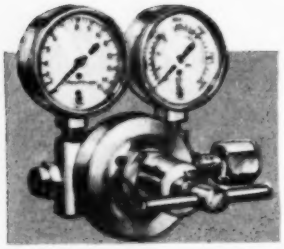
Good news followed quickly: "Leakers" became a thing of the past, for these twice-wrought, dense-grained forgings are gas, air and water-tight. Rejects during machining dropped from an average of 18% to less than 1%. Combined tooling and machining costs were cut in half!

In this instance, the switch to Anaconda Die Pressed Forgings resulted in a net saving of 22%—with rejects and costs *down* . . . dependability and profits *up*.

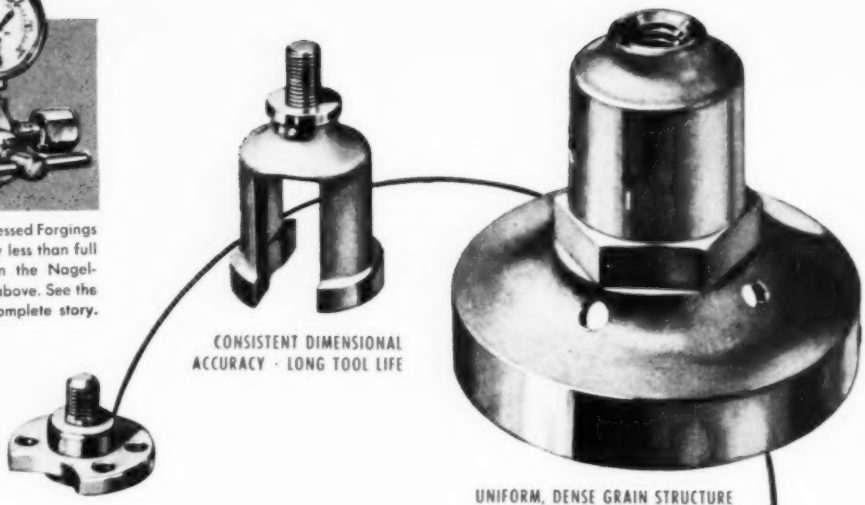
ANACONDA

THE AMERICAN BRASS COMPANY, General Offices: Waterbury 88, Connecticut

Perhaps similar savings could be made on your product . . .



The five Anaconda Die Pressed Forgings illustrated here in slightly less than full scale are being used in the Nagel-dinger Regulator shown above. See the previous page for the complete story.



CONSISTENT DIMENSIONAL ACCURACY · LONG TOOL LIFE

UNIFORM, DENSE GRAIN STRUCTURE GAS, AIR AND WATER-TIGHT

SMOOTH TEXTURE— LOWER FINISHING COSTS

Don't be misled by their good looks!

Of course they're handsome, but make no mistake—these die pressed forgings are huskies throughout... solid, dense-grained working metal, with twice the strength of ordinary sand castings.

They're easy to machine, too—and more uniform than peas in a pod. Often it's simply a matter of drilling and tapping a few holes, threading a boss, or machining a mating fit—and they're ready for assembly.

If the production of unusual shapes is taking too big a bite out of your profits, send us a drawing, pattern or sample part, together with functional data. There's a very good chance that we'll be able to help you... we've done it hundreds of times for others. For general information on Anaconda Die Pressed Forgings, write for Publication B-9.

48122

THE AMERICAN BRASS COMPANY
General Offices: Waterbury 88, Connecticut
Subsidiary of Anaconda Copper Mining Company
In Canada: Anaconda American Brass Ltd., New Toronto, Ont.

ANACONDA

Anaconda
DIE PRESSED FORGINGS

AVAILABLE IN COPPER, BRASS, BRONZE AND SPECIAL COPPER ALLOYS

How THE PRESSED STEEL CO. CONTAINERS

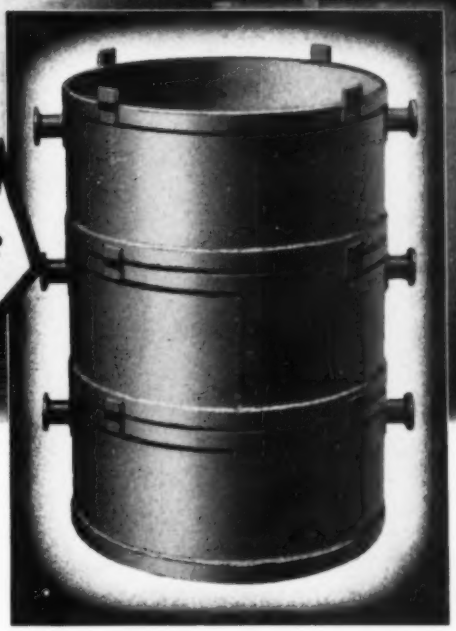
CUT HEAT-TREATING COSTS

The sheet alloy baskets, pictured at right, were fabricated by The Pressed Steel Co. to replace cast alloy baskets in a battery of gas carburizing furnaces. In contrast to a maximum life of 3,000 hours for the old baskets, the sheet alloy units were still in good condition after 20,000 hours. This represents a substantial saving in replacement costs. But now add these further savings, resulting from the fact that the sheet alloy baskets weigh 2/3 less:

1) FUEL SAVING--Need less time to attain pot heat.
2) LABOR SAVING--Handle easier and faster.
3) SPACE SAVING--Increase furnace capacity.

Equipment for Every Heat-Treating Purpose

"Pressed Steel" light-weight sheet alloy heat-treating units are furnished in any size, design or metal specification: boxes, covers, baskets, racks, tubes, retorts, etc. As pioneers of welded alloy heat-treating equipment, we offer you a wealth of experienced engineering assistance and production know-how. Send blue prints or write as to your needs.



Light-weight sheet-alloy basket to replace cast units in a battery of carburizing furnaces. "Pressed Steel" fabricates containers and covers for every heat-treating purpose.

THE PRESSED STEEL COMPANY
of WILKES-BARRE, PENNSYLVANIA

Industrial Equipment of Heat and Corrosion Resistant WEIGHT-SAVING *Sheet Alloys*

☆ ☆ ☆ OFFICES IN PRINCIPAL CITIES ☆ ☆ ☆

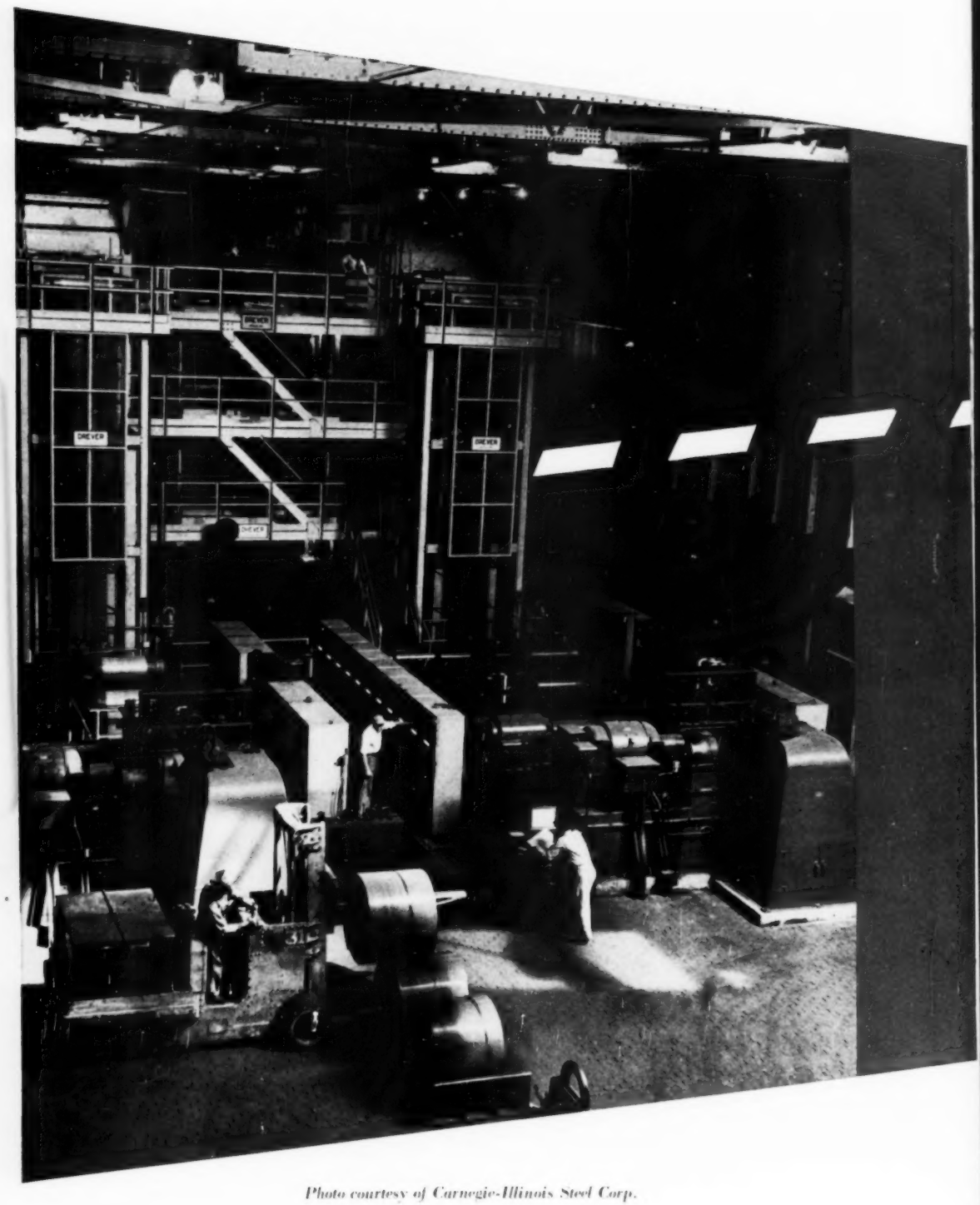


Photo courtesy of Carnegie-Illinois Steel Corp.

DREVER

VERTICAL STRIP ANNEALING FURNACES

improve silicon steel production facilities

IN CARNEGIE-ILLINOIS VANDERGRIFT PLANT

The coiled silicon steel from these two continuous furnace lines recently put in operation in this U. S. Steel Plant, is very flat from edge to edge. Users of this strip report excellent surface characteristics which tend to increase stamping die life.

Drever continuous annealing lines for Tin Plate, Galvanizing Stock, other Low Carbon Steel and Non-Ferrous Strip in capacities up to 30 tons per hour, provide an economical investment in tonnage production of quality material.

Detailed information upon request.

DREVER CO.

790 E. VENANGO ST., PHILA. 34, PENNA.

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IOWA, MINN. & WIS.—WALTER G. BARSTOW, 1302 FIFTH AVE. SOUTH, MINN. 4, MINN.

A complete line consists of two uncoilers for handling cold reduced coils; multiple seam welder; continuous strip cleaner; looping pit to secure accurate guiding and tensioning of strip through furnaces; 13 zone controlled atmosphere annealing furnace, with cooling tower; drive bridle for forwarding strip; guiding and controlled tensioning for recoiling; 2 recoilers. The coils come out absolutely square.

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WIRE CLOTH PROBLEMS

Whether you use wire cloth in the manufacture of original equipment, or in a processing operation, the manufacturing facilities and experience of two great woven wire producers are available to save you time and money in the fulfillment of your requirements.

With plants on both the East and West Coasts, The Wickwire Spencer Steel Division and The California Wire Cloth Corp. are pioneers in the territories they serve. As precision fabricators of a dozen different weaves of wire cloth, we can supply wire cloth for screening, filtering, grading, cleaning or processing. Wissco and Calwico Wire Cloth is made in all commonly used metals to give long service under chemical action, corrosion, abrasion, moisture or high temperature.

If you have questions regarding wire cloth, the services of our engineers are at your disposal. Just write to our nearest office.

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CALWICO *On the Pacific Coast*
THE CALIFORNIA WIRE CLOTH CORP.
1080—19TH AVE., OAKLAND, CAL.

here's how Microcastings

solved a critical camera problem

The Bell & Howell lens plate for the Sportster Camera shown above is an example of the intricate design problems involving thin wall sections, close location of holes, and exact tolerances which can be economically solved by the MICROCAST process.

BELL & HOWELL, leading manufacturers of motion picture equipment, found the answer to a critical and costly lens plate problem in MICROCASTINGS.

The intricate, stainless steel lens plate, too complicated for economical die casting or machining, was formerly coined of brass. However, coining dies did not stand up; and the cost of die maintenance was prohibitive.

Today the MICROCAST process has eliminated extensive and expensive die costs as well as machining cost . . . *another example of how* MICROCAST *is serving American industry, solving difficult problems on small castings.*

PARTS NEVER before thought practicable for castings are being MICROCAST and are proving superior for service in consumer as well as commercial products.

Perhaps you have a parts problem involving factors of intricate design, high melting point alloys, or high machining costs. Austenal engineers are at your service and will be pleased to work with you on any of these problems.

NEW CATALOG AVAILABLE

A copy of the new 16 page book, "New Horizons with Microcasting," is yours upon request. It is the most complete report ever published on the subject of the MICROCAST process originated by Austenal Laboratories, Inc. See our catalog in Sweet's File for Product Designers.

MICROCAST PRECISION CASTINGS PROCESS

The name MICROCAST is a registered trademark of the Austenal Laboratories, Inc.

MICRO CAST

MICROCAST DIVISION
AUSTENAL LABORATORIES, INC.
224 East 38th Street • New York 16, New York
715 East 69th Place • Chicago 37, Illinois

Aluminum does them all—but . . .

Naturally, you don't make pots and airplanes with the same alloy.

To manufacture the products illustrated above, a *variety* of alloys and tempers of aluminum are required—each suited to the specific requirements of the job.

How about *your* product? Does it fully utilize aluminum's advantages?

A change in alloy or temper may enable you to *improve your product* by giving it:

Increased strength . . . reduced weight . . . improved finish . . . greater durability.

Furthermore, by making a change in alloy or temper you may be able to *reduce your manufacturing costs* through:

Lower material cost . . . fewer fabricating steps . . . lower rejection rate . . . lower finishing costs.

Sometimes a minor change in product design—enabling use of a different alloy—will result in one or more of these benefits.

So ask yourself if you're taking fullest advantage of aluminum's remarkable versatility. If there's any doubt, call in a Permanente Metals' engineer and he'll give you the answer!

Permanente Metals

PRODUCERS OF

Kaiser Aluminum

SOLD BY PERMANENTE PRODUCTS COMPANY, KAISER BUILDING, OAKLAND 12, CALIFORNIA . . . WITH OFFICES IN:
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One of the many ways that

industry makes multiple savings with Gulf Quality Oils and Greases:

Artist's drawing of 1,000-ton oil-hydraulic press in a large Middle Western manufacturing plant. The hydraulic system is protected against corrosion and sludge deposits by the use of Gulf Harmony Oil.

GULF HARMONY OIL

insures better performance of oil-hydraulic equipment, prevents corrosion

Today practically every industry is making greater use of versatile oil-hydraulic power to drive and control production equipment.

A vital factor in oil-hydraulic machine operation is the selection of the proper hydraulic oil. Gulf Harmony Oil meets the most exacting requirements for this type of equipment. It provides outstanding protection against wear of all types of rotary pumps, cylinders, and control mechanisms, and keeps leakage to a minimum.

Highly resistant to oxidation and emulsification, Gulf Harmony Oil lasts indefinitely and resists formation of harmful sludge deposits — insures freedom from jerky feeds, chattering, and loss of accuracy. In the many plants where this quality oil is used, there is tangible evidence of better hydraulic equipment performance, less out-of-service time, fewer part replacements, and lower maintenance costs.

Gulf Harmony Oil is one of more than 400 Gulf quality oils and greases that are helping plant operating men make multiple savings through improved production and lower costs. Make sure your plant is getting the advantage of all recent developments in petroleum science. Write, wire, or phone your nearest Gulf office today and ask a Gulf Lubrication Engineer to call.

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Helps make machines produce more at lower cost

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Operator using the new Model No. 1506 low speed polisher. Section of laboratory equipped with No. 1251 Duo Belt Sander—No. 1700 Electro Polisher—No. 1315 Press.

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. . . provides the metallurgist with the most complete line of modern designed precision machines for specimen mounting and preparation available anywhere in the world. This finely made equipment has been developed through a thorough understanding of the requirements of the metallurgist and a rigid insistance on perfection in the mechanical design and construction of each item.

Everything needed for metallurgical testing from cut-off machines, moulding presses, and grinders to the mechanical or electrolytic polishers is included in the Buehler line.

In setting up complete laboratories or adding items to present equipment the metallurgists will find in the Buehler line of coordinated equipment everything needed for producing the best work, with speed and accuracy.

THE BUEHLER LINE OF SPECIMEN PREPARATION EQUIPMENT INCLUDES . . . CUT-OFF MACHINES • SPECIMEN MOUNT PRESSES • POWER GRINDERS • EMERY PAPER GRINDERS • HAND GRINDERS • BELT SURFACERS • MECHANICAL AND ELECTRO POLISHERS • POLISHING CLOTHS • POLISHING ABRASIVES

Write for bulletin of new equipment or information on any specific item. We invite correspondence relative to setting up complete laboratories suitable for any particular requirement.

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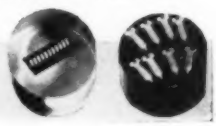

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HIGH SPEED STEELS

RED CUT SUPERIOR—America's best known tungsten high speed steel—for all cutting purposes.

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VAN-LOM and 8-N-2—Molybdenum high speed steels, for general cutting purposes.

RED CUT COBALT—Extra Duty—heavy cuts, fast speeds, hard or abrasive materials.

GRAY CUT COBALT—Super Duty—hogging cuts, high speeds, heat treated or abrasive materials.

NEATRO—Superior Wear Resistance—delivers top performance on non-ferrous materials, cast steel, cast iron, heat treated steels.

VASCO SUPREME—Entirely New—higher hardness, higher wear resistance, higher hot hardness, higher speeds.

We do not compromise quality by combining in a single plant the manufacture of carbon and alloy tool steels with High Speed Steels. Our Vanadium Works* is devoted entirely to the manufacture of High Speed Steels, and is the only plant in the world so constituted . . . with melting furnaces, heating furnaces and furnace atmospheres, roll designs and even hammer blocks designed especially for the purpose—and used by men trained as specialists. NO WONDER these are *First Quality* High Speed Steels. Come and see for yourself—anytime.

*(Carbon and Alloy Tool Steels are made at our Colonial Works)

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Vanadium-Alloys Steel Company

COLONIAL STEEL DIVISION

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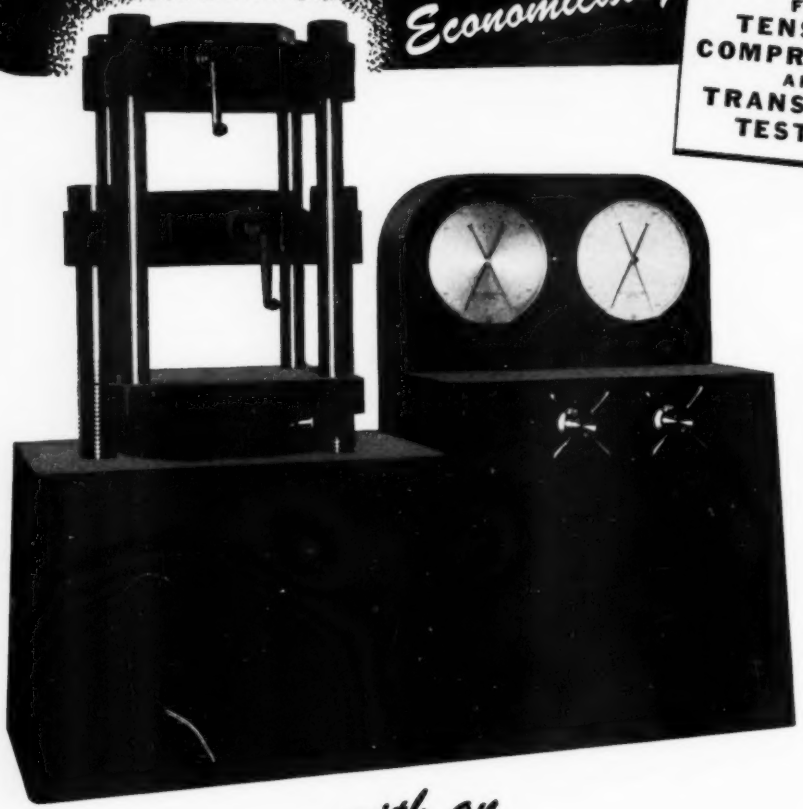
YOU CAN HAVE A COMPLETE TESTING LABORATORY
Economically

FOR TENSION, COMPRESSION AND TRANSVERSE TESTING



Olsen 400,000 lb. "L" Type Hydraulic Universal Testing Machine

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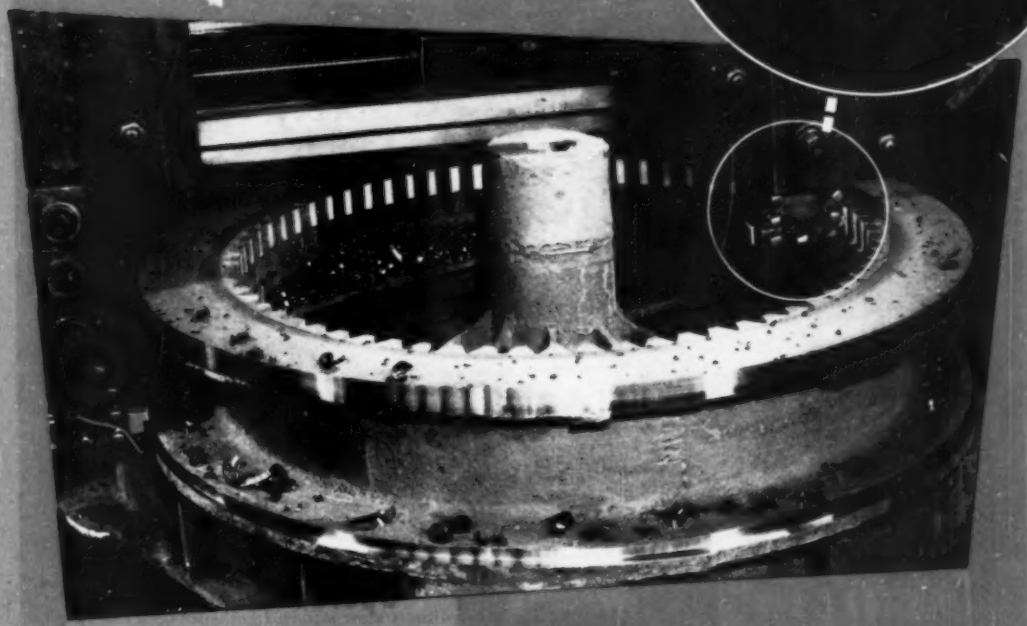
2030 Easton Rd., Willow Grove, Pa.

- **OLSEN "L" TYPE HYDRAULIC UNIVERSAL TESTING MACHINE**
- **OLSEN MECHANICAL EXTENSOMETER**
- **OLSEN COMBINATION 1" TO 2" GAGE PUNCH**
- **OLSEN "RAPID-ACTION" PERCENTAGE SCALE**

Available in 60,000, 120,000, 300,000 and 400,000 pound capacities each Olsen "L" Type Universal has an additional range of 1/5 or 1/6 capacity. No other testing equipment can give this accurate, dependable and convenient service at such a *low cost!*

THIS FIRTHITE TOOL TAKES

a thousand blows a minute



A thousand blows a minute, day after day, on an interrupted cutting job . . . that is real punishment for a carbide tipped tool.

FIRTHITE, grade T04, takes this severe assignment in stride—stays sharp, doesn't chip or break—taking a 3/8" cut on a 72" boring mill, boring cast steel gear teeth at a speed of 175 feet per minute. Feed, 0.016" per revolution.

For that tough cutting job in your shop, get in touch with a Firthite Engineer.

Call **Firth Sterling**

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All along the Line
Furnaces for every Heat-Treating Operation . . . .
Loftus Engineers, Designs and Constructs complete plants and individual furnaces.
Every step along the way — From the Open Hearth to the Heat-Treating Line — The Loftus organization serves the metallurgical field from melting and refining to the finished heat-treating product.
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FOR
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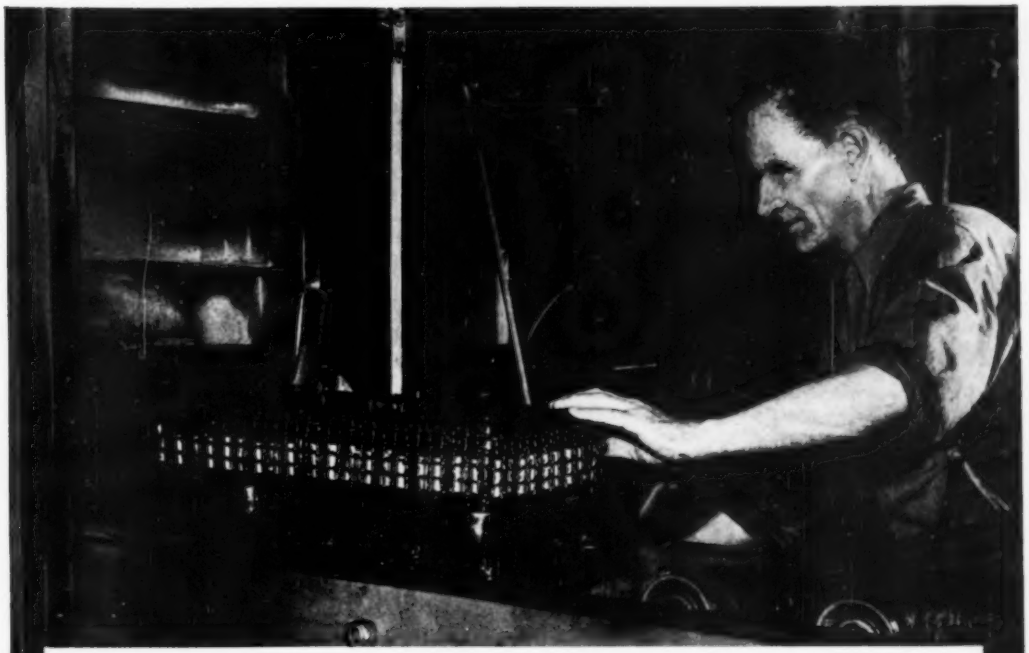


Inconel fixtures still in carbo-nitriding service ...after 6,240 hours at 1650° F.

HERE is how one of the world's largest passenger car manufacturers solved a difficult problem in severe carbo-nitride case hardening operations.

The carbo-nitriding furnaces were running on a 24 hour a day, 5 day week schedule. The furnaces —radiant tube fired, muffle gas type—operated at 1650° F. At the end of each 2 hour operating cycle, work and furnace baskets were oil quenched at 120° F.

The problem was to find furnace baskets that could stand up under such destructive service conditions. Corrosion, scale, embrittlement, and mechanical distortion were destroying baskets after as little as 3 or 4 weeks' service.

Baskets made of various metals were tried with little success. Finally, production engineers called for INCONEL.* Result? *One year later, the maintenance report read: "Inconel furnace baskets still in service!"*

Needless to say, this manufacturer, like hundreds of others, has standardized on INCONEL for this service.

If your own production problems demand a metal that will resist scaling and corrosion, and maintain mechanical strength at high temperatures — try INCONEL. This 80 Nickel-14 Chromium alloy is daily proving to be an outstanding metal for heat-treating equipment.

Write for: *"Inco Nickel Alloys for Long Life in Heat Treating Equipment."* Inco's Technical Service will gladly make specific recommendations.

*Reg. U. S. Pat. Off.

EMBLEM OF SERVICE INCO

THE INTERNATIONAL NICKEL COMPANY, INC. • 67 Wall Street, New York 5, N. Y.

INCONEL —for long life at high temperatures

(80 NICKEL—14 CHROMIUM)

Variety of Equipment used by

SUPERIOR METAL TREATERS, INC.

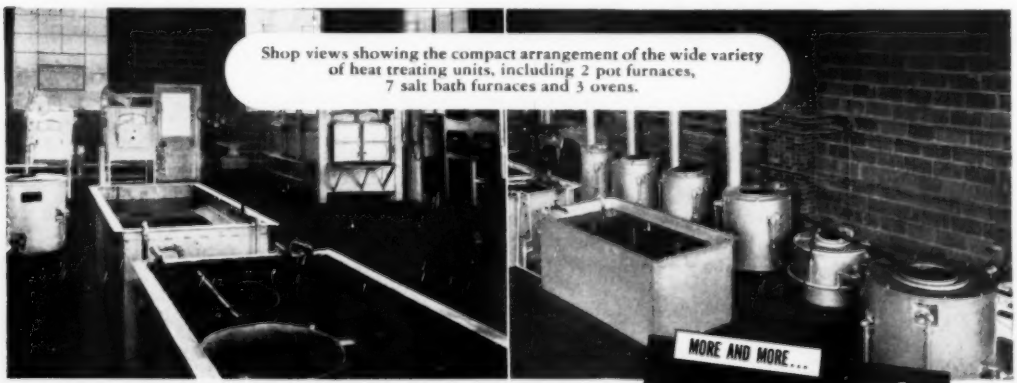
Emphasizes the Versatility of GAS

VARIETY is one of the most characteristic features of a commercial heat treating shop—variety of customer demands and variety of equipment required to fulfill them.

With a background of 22 years experience, Evan D. Ehmann, President of Superior Metal Treaters, Inc., knew just what to look for when he established his Newark, New Jersey, shop. This modern plant has the productive capacity to cope with the miscellaneous requirements of many customers.

Key feature of the installation is the versatility of the equipment. Each unit was chosen for its ability to perform under a number of different conditions. In selecting this equipment Mr. Ehmann determined to use GAS because, as he expresses it, "**During my years in this business I discovered that Gas Equipment provided the accurate control, economical operation, and versatility we needed. The precise temperatures and speed of heating we obtain with GAS mean a lot of extra production in our shop.**"

Whether the heat treating process is a production-line application, or a commercial shop operation, the flexibility of GAS and the versatility of modern Gas Equipment are important economic factors. The characteristics of GAS make it stand out in any comparison with other available fuels for heat processing.



Shop views showing the compact arrangement of the wide variety of heat treating units, including 2 pot furnaces, 7 salt bath furnaces and 3 ovens.

AMERICAN GAS ASSOCIATION
420 LEXINGTON AVE., NEW YORK 17, N.Y.

For consistently fine stainless steels, specify

VANCORAM FERRO CHROMIUM

SELECTED TO RESIST NITRIC ACID on the inside surface and atmospheric conditions on the outside, the stainless steel installation shown in the accompanying photograph has a record of over twenty years of satisfactory service.

This is a highly successful use of just one of the more than forty cast and wrought types of stainless steel available for resistance to chemicals, or sea water, or dyes, or foodstuffs, or numerous other environments for which they have already proven highly advantageous.

Regardless of the type, however, *quality* and *precise analysis* are primary requisites for success. To insure production of consistently fine stainless steels, Vancoram Brand Ferro Chromium is available, made by closely controlled processing methods and from carefully selected raw materials. The low-carbon grades for the manufacture of stainless steel are supplied with a carbon content from 0.06% max. to 2.00% max., all containing from 67% to 72% chromium.

If you have a technical problem involving the making, treatment, fabrication, properties, or performance of stainless steel, our metallurgical engineers will be glad to help you solve it.

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Precision Subcut—
Submerged Specimen Cutter

WHEN all raw materials are uniform *you know* that your production will exceed your average standards, and . . . that your quality is at its very best. • You can *know* that your materials are uniform through Metallographic Inspection, the science that provides *pre-determined* production standards and quality. • Our new 32-page catalog contains helpful information and listings of the very latest in equipment for preparing specimens for inspection. Write for your copy today.

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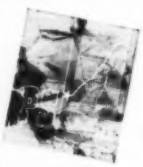

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Bulletin on SUPER REFRACTORIES by CARBORUNDUM

TRADE MARK

NO. 1 MARCH, 1949

Where Do Super Refractories Fit?

Super Refractories, as produced by CARBORUNDUM, are designed to augment the more commonly-used refractories. They fit in where the latter materials, for one reason or another, do not measure up to thermal, physical and or chemical requirements.

The characteristics of super refractories by CARBORUNDUM often make them the logical first choice in terms of cost of production or quality of work produced. High heat resistance is an outstanding property. These brick, tile and shapes stand up under temperatures that lead to the failure of other refractories. However, super refractories by CARBORUNDUM are often specified for other product properties . . . even at relatively low temperatures.

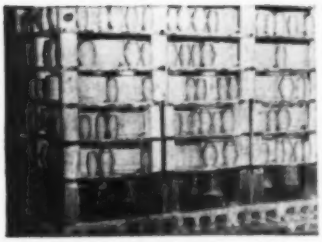
In effect, the line of super refractories by CARBORUNDUM are specialized products—custom-built—for specific requirements. They provide effective resistance to abrasion, spalling, chemical corrosion and thermal shock. They stand up under fast and frequent temperature changes.

The use of super refractories by CARBORUNDUM . . . either in complete structures or in localized trouble areas . . . results in longer refractory life, lower replacement cost, uniform production cycles, faster and less frequent cleaning and stepped up production. They give you lowest all-around refractory cost per product unit. Support for this fact is given in the installation data reported in this bulletin.

Physical Properties of Super Refractories by CARBORUNDUM

TRADE MARK

	CARBOFRAX	MULLFRAX	MULLFRAX S	ALFRAX K	ALFRAX B	ALFRAX BI
Heat Conductivity at 2200°F. in BTU/hr. sq. ft. and °F./in. of thickness	109 BTU	15 BTU	9 BTU	21 BTU	12 BTU	7 BTU
REFRACTORINESS PCE CONE	37-40	38-39	37-38	37-39	39-40	38
SPALLING RESISTANCE	High	High	High	Medium	Good	Good
ABRASION RESISTANCE	High	Medium	Medium	High	Medium	Low
THERMAL EXPANSION	Low	Medium	Medium	Medium	Medium	Medium
SPECIFIC HEAT	0.285			0.330		0.320
WEIGHT 9 IN. STRAIGHT	9.25 lbs.	9.5 lbs.	7.8 lbs.	10.1 lbs.	7.25 lbs.	4.5 lbs.



Switch to Super Refractories Increases Load "Fill" by Over 15%

Increased capacity plus considerable savings in time, money and trouble more than justify the change-over from saggers to open setting of super refractories in the case of this hotelware plant. Setters and posts support the ware load on kiln cars put through a direct fired continuous kiln on a 72 hour cycle. Operating temperature is 2300°F.

Since the switch to CARBOFRAX silicon carbide setters and MULLFRAX electric furnace mullite posts—output has increased, rejects and costs are lower. Extended service life and thermal shock resistance cut down the necessity of frequent car rebuilds . . . offer additional savings in both labor and material costs.

Super Refractories Withstand an 11 Year "Beating"

The super refractory brick installed in the fuel bed of this boiler furnace has been in continuous on-line service for more than a decade. CARBOFRAX silicon carbide brick has given this cost-cutting performance under conditions of flame erosion and mechanical abrasion as well as high temperatures. Its hard dense face resists clinker embedment and is unharmed by barring and cleaning. It possesses a high refractoriness as well. That is why it provides an excellent foundation for upper walls while preventing frequent outages in the hot punishment zone.

For these same reasons, CARBOFRAX brick and flue linings are preferred in water gas machine installations where their service provides more gas make at lower cost per MCF of gas produced.

"Carborundum," "Carbofrax," "Mullfrax," "Silfrax," "Alfrax" are registered trademarks which indicate manufacture by The Carborundum Company

Address all correspondence to: Dept. J-39, THE CARBORUNDUM COMPANY, Refractories Division, Perth Amboy, New Jersey

Continued on other side →

← Continued from other side

Super Refractory Slag Hole Blocks Assure Continuous Runs

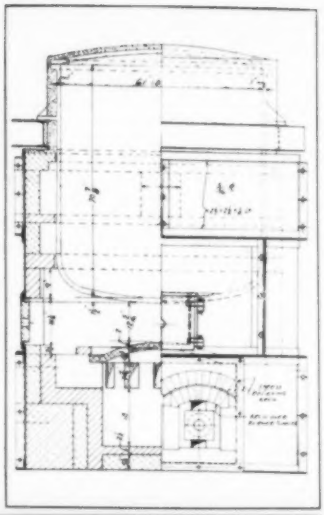
CARBOFRAX silicon carbide slag hole blocks are particularly resistant to slag erosion at high temperatures. A uniform hole size is maintained throughout continuous pour cupola runs—with no enlargement even when the blast is on. A constant slag stream is assured for twenty-four and even more hours. Costly shutdowns for replacement are avoided. Slag hole blocks are immediately available from stock in standard sizes. Special sizes are made to order.

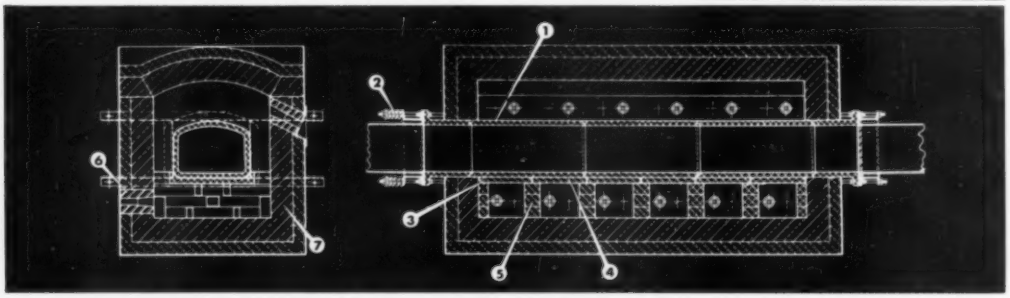
Unique Properties Provide Advantages in Low Temperature Applications →

Because super refractories are so closely identified with high temperatures, their advantages in the low temperature range are often overlooked. In this application, the charge is only heated to 350°C. Yet, because of a thermal conductivity 11 to 12 times that of fireclay, the CARBOFRAX silicon carbide arch radiates heat to the pot faster. Working temperature is attained with a reduced heat head.

Combustion chamber temperatures are lower. Because gases are at lower temperatures around the cast iron pot they are not as destructive. Life of both kettle and setting are extended with no repairs required after 5 years of service. Formerly, pots lasted about 6 months.

As a further aid to heat transfer, the CARBOFRAX arch may be half the thickness of fireclay—yet possess 3 to 4 times the mechanical strength. Strong resistance to cracking and spalling assures long, trouble-free service. This same advantage is realized in controllable offtake ports, lined with MULLFRAX S converted kyanite brick, which easily withstand temperature fluctuations.





Muffle Furnace Installation Exemplifies Versatility and Variety of Super Refractories

Several types of super refractories by CARBORUNDUM are used to advantage in this large muffle furnace with artificial atmosphere which employs sectional muffle with support plates and end compression.

1 The sectional CARBOFRAX muffle assures extended service with freedom from cracking and mechanical wear or frequent replacement. Exceptional refractoriness permits more continuous higher temperature operation without deterioration. At a lower initial cost, CARBOFRAX muffles approach the thermal conductivity of alloy steel at working temperatures. Furnace production is increased. Fuel cost remains about the same. Maintenance expenses drop.

2 Tight joints to prevent leakage of artificial atmosphere and permit muffle expansion and contraction are provided by spring compression.

3 CARBOFRAX support plates provide a continuous level bearing for the muffle. They are unaffected by high temperatures and resist cracking.

4 Various units are free to move independently on heating and cooling because of a special bedding cement developed to prevent sticking. This feature also simplifies any necessary replacements.

5 MULLFRAX or CARBOFRAX piers provide excellent support because they retain a high load-bearing strength at high temperatures. After extended service, there is no sagging or slumping.

6 Less attention is required for burner tunnels rammed with ALFRAX cement or formed with MULLFRAX S prefired blocks. Resisting flame erosion, spalling and cracking—they help maintain the hole size and thereby provide more efficient combustion conditions.

7 ALFRAX BI or MULLFRAX S linings withstand extreme high temperatures for extended periods without deformation. Heat is retained because of a low thermal conductivity. Worthwhile savings are realized. More continuous furnace operation is assured.

A complete file of informative literature covering super refractories is available through The Carborundum Company. There are facts and figures on installations in specific fields. To obtain copies of reports, booklets and catalogs of particular interest is a simple matter. Merely select from the list printed here. Copies will be sent you at once. No obligation, of course.

Super Refractories by CARBORUNDUM (general catalog)
Super Refractories for the Ceramic Industry
Super Refractories for the Process Industry
Super Refractories for Boiler Furnaces
Super Refractories for Heat Treatment Furnaces
Super Refractories for Gas Generators
The FRAX Line of SR Cements
CARBOFRAX Refractories Skid Rails
Bulletins Nos. 1, 2, 3 on Underdrain Systems and Diffuser Media.

Dept. No. J-39

THE CARBORUNDUM COMPANY
Refractories Division
PERTH AMBOY, NEW JERSEY

METAL PROGRESS

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Ernest E. Thum, *Editor* Taylor Lyman, *Associate Editor*

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WANTED: BETTER CRITERIA FOR TURBINE ALLOYS

By W. O. Sweeny
Haynes Stellite Co.
Kokomo, Ind.

THE PRODUCTION and use of alloys for high temperatures (the "superalloys", as they are sometimes called) has been hastened by the rapid development of the all-important turbojet engines for fast military aircraft. At the very start the superalloys were used in exceedingly severe service for turbosupercharger buckets moving at high speeds, impelled by the exhaust gases from reciprocating engines, gases that reached temperatures of 1500° F. Recent evolution of the turbojet engines, and the realization that these are not only the motive power for aircraft of the future but also of the present, has resulted in the adaptation of the superalloys to more and more critical parts of this type of engine. Since the thermal efficiency of the turbojet is increased appreciably with only a small increase in the working temperature of the gases, there is a great incentive to produce metallic alloys which can be cast or worked into precise shapes and which will withstand the action of corrosion and stress at high temperature. Concurrently with the development of the aircraft engine whose useful life is measured in hundreds of hours comes the gas turbine for locomotive, steamship or central station with a life to be measured in decades.

These well-known facts are restated primarily to indicate the magnitude of the problem before metallurgists and mechanical engineers. When the real demand occurred during the last war, American metallurgists had enough information about fabrication and performance to recommend for these services Type 317 stainless steel (18 Cr, 12 Ni, 3½ Mo), and several alloys based on cobalt and chromium (the "Stellite" alloys, "Vitallium", "K-42-B"). As a result of intensive studies since then a number of complex alloys (mostly variations within the two main alloy families mentioned above) have been studied. Basically, they may be classified as follows:

GROUP A — Wrought alloys that exhibit high strength at elevated temperatures as a result of strain hardening.

GROUP B — Wrought alloys with high strength at elevated temperatures which can be further improved by heat treatment.

GROUP C — Alloys used in the cast condition and which are inherently strong at elevated temperatures.

A rating of these alloys is contained in a diagram presented during the round-table discussion on superalloys at the 1946 convention (see p. 106, *Metal Progress* for July 1946), from which Table I is taken.

By such ratings it is obvious that in Groups B and C metallurgists have supplied materials of greatly improved high-temperature strength and stability.

The extent to which these alloys are being accepted is demonstrated by the fact that the Society of Automotive Engineers has issued Air-

craft Material Specifications covering these alloys, both in precision-cast form and in wrought form. The S.A.E. subcommittee covering high-temperature alloys has been headed by A. W. F. Green, chief metallurgist of the Allison Division of General Motors Corp. Under his vigorous leadership specifications on a number of the materials were issued as early as September of 1947, and valuable information about their properties and the varied experiences of the users have been freely interchanged. The data available have been gathered from numerous laboratories throughout the United States. Many of these projects have been Government-sponsored, but many others have been carried on at the instigation of private companies and in the universities.

The three mechanical properties of these alloys that have received the most attention, and on which the most emphasis is placed, are stress-rupture, short-time tensile properties at elevated temperature, and endurance strength at elevated temperature. It is not within the scope of this paper to discuss the various alloys on such a basis; it is however the object to raise some questions as to whether these tests are sufficient to discriminate between alloys as to their performance in service, and to make some suggestions concerning fields where *further* investigations would bring important results.

Limitations of Laboratory Tests

It is our belief that the laboratory data serve only as an indication of the uses for which these alloys appear to be suitable. At the present time, the final choice of material is dependent upon long-time service testing in the turbine unit. An example of the lack of agreement on any one alloy for a specific application is shown by the fact that Haynes Stellite Co. is currently making five cobalt-base alloys for precision-cast turbine buckets. Allison thinks No. 21 alloy is best, yet Westinghouse has always used No. 23 alloy. Likewise, other turbine builders feel that alloys No. 27, 30, or 31 are definitely advantageous for their specific conditions. A quick but accurate comparative means of evaluating how metals will react in gas-turbine service is clearly needed.

First let us enumerate the conventional tests and summarize some of the derived information:

For the past five years, it has been standard practice (fostered by the use of A.M.S. specifications) to conduct short-time tensile tests at room and elevated temperatures on each master heat of alloy for precision castings. These tests are made on as-cast ¼-in. diameter specimens, and determine ultimate strength, elongation, and reduction of area. (Yield strength is seldom noted, since most laboratories are not yet equipped with extensometers capable of measuring this property at elevated temperatures.)

Table I — Range of Stress-Rupture and Creep Properties

	18-8 Mo	Group A	Group B	Group C
Temperature for rupture in 1000 hr. under 20,000-psi. stress	1270° F.	1340/1400° F.	1375/1500° F.	1450/1530° F.
Stress to produce rupture in 1000 hr. at 1400° F.	11,000 psi.	15,000/20,000 psi.	18,000/28,000 psi.	24,000/31,000 psi.
Temperature for secondary creep rate of 1% in 10,000 hr. under 10,000-psi. stress	1250° F.	1320/1400° F.	1370/1500° F.	1460/1600° F.
Stress to produce secondary creep rate of 1% in 10,000 hr. at 1400° F.	5000 psi.	7500 psi.	9000/14,000 psi.	12,500/15,500 psi.

A.M.S. specifications call for a single testing temperature, but Haynes Stellite Co. has made extensive tests at temperatures from room to 1800° F. (Scatter of results, heat-to-heat of a given alloy, has been minor.) We have also made a limited number of tests on alloys aged 50 hr. at 1350° F., and find that their short-time strength is considerably higher than the as-cast test bars, tested at corresponding temperatures, particularly in the 1000 to 1200° range. Figures for elongation and reduction of area ("ductility") are generally lowered by the aging process. (It should be remembered that an as-cast, unaged part operating at high temperature will age during service.) Representative figures are given in Table II.

It will be observed that differences noted when testing at 1200° F. are not nearly so pronounced at 1500° F. At 1800° F. all these alloys in both conditions will break at 34,000 to 38,000 psi. in short-time tensile tests; obviously aging at 1350° F. is not beneficial at really high temperature.

Stress-rupture tests were run extensively on the superalloys by many laboratories throughout

the United States during and since the war. The spread of results before adoption of A.M.S. specifications has been wide, due to variations in chemical analysis, variations in aging prior to test, and in testing conditions at different laboratories.

As will be pointed out later, considerable work needs to be done in determining the normal scatter of stress-rupture properties of these alloys to be expected when castings are made in a single plant under production control.

Table II — Short-Time High-Temperature Tensile Strength of As-Cast and Aged* Bars

Alloy		At 1200° F.		At 1500° F.	
A.M.S. Specification	Haynes' Designation	As-Cast	Aged*	As-Cast	Aged*
A.M.S. 5385	H.S. No. 21	74,000	86,000	54,000	58,000
A.M.S. 5375	H.S. No. 23	82,000	94,000	56,000	58,000
A.M.S. 5378	H.S. No. 27	50,000	66,000	45,000	51,000
A.M.S. 5380	H.S. No. 30	60,000	78,000	51,000	57,000
A.M.S. 5382	H.S. No. 31	77,000	76,000	—	60,000

*Aged at 1350° F. for 50 hr.

In the early development of the gas turbine, there was considerable concern over the possibility of fatigue failures because of the naturally low damping characteristics of the cobalt-base materials. Experience to date indicates that this concern was not justified, as fatigue failures have not been a major problem. The data available on the endurance strength is meager. Endurance testing at elevated temperatures presents a difficult problem and very often the results that are obtained, after the long test period is completed, are greeted with skepticism.

However, at 1200° F., the endurance of the cast materials is slightly lower than the better wrought alloys, but at 1500° the endurance of the strongest cast materials is as good as, or better than, the best of the wrought materials. In all other respects also, precision cast vanes and buckets show their superiority over wrought, with increases in temperature or in time. Up to 1350° F., there might be some question as to whether it is better to use wrought or cast turbine buckets, other considerations being equal. However, above 1350° F. precision castings have better yield strength, better stress-rupture, better creep resistance, and lower stress-elongation values.

Naturally, for such parts as tail cones, combustion liners, and exhaust stacks, the wrought materials will continue to be standard.

Since most designers are aiming at longer life and higher temperatures for better efficiency, both the metallurgist and the engineer have a fundamental challenge of a different sort — that is, to develop a laboratory test for evaluating materials that will correlate closely with service experience. Until such a measuring stick becomes available, the full development of better alloys will be impaired. Before it can be applied, a great amount of new data must be assembled.

Uniformity, Piece to Piece

For example, it was mentioned that the stress-rupture data have been limited to a small number of tests. Currently, we at Haynes Stellite Co. are carrying out a program to determine the scatter of these superalloys in precision-cast form. Figure 1 shows the scatter obtained with 64 stress-rupture bars, which were cast from a single master heat in eight molds. The lower portion shows the scatter of eight castings made within a given mold. All of these 64 specimens came from a single heat of average composition for alloy No. 21. Additional work is now being carried out on heats with the chemical analyses on the high side of the range and on the low side of the range, in an attempt to determine not only the variations due to differences within the mold, and from mold to mold, but also variations from heat to heat.

The purpose of this work is to arrive at a minimum value of stress-rupture so that the engineer can have positive data on which to base his design. A secondary objective is to determine the cause for scatter and to minimize it. This is a long-term program which is believed

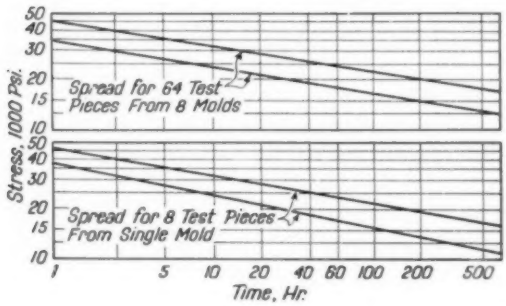


Fig. 1 — Stress-Rupture Properties at 1500° F. of Single Heat of Vitallium (Haynes Stellite Alloy No. 21; 64% Co, 28% Cr, 6% Mo, 2% Ni, 0.25% C) Precision Investment Cast. Tested as-cast after cleaning by sand blast

to be the first attempt to obtain this type of stress-rupture data.

A matter for serious consideration is the quick failure of an occasional bucket — whether forged or cast. A wheel with 45 to 100 buckets, apparently all alike, may lose one or two buckets prematurely, whereas the balance, after the failed bucket is replaced, will run the full expected life. The short-lived buckets do not exhibit detectable defects or any other characteristic that differentiates them from the good buckets. Since the turbine wheel is only as good as the poorest bucket, it would be a valuable contribution if some means could be developed for detecting it.

Too little is known about grain size and grain orientation and their effects on parts subjected to high stresses at elevated temperatures. About three years ago, a theory was evolved that cast buckets with fine grain size would be better because they would have higher endurance strength. However, when subjected to service conditions in Allison I-40 and General Electric TG-180 engines, fine-grained cast buckets were found to be definitely inferior to regularly cast buckets with larger grains.

A thorough investigation of both grain size and orientation is clearly needed. For this study to be of real value, round test bars should not be used since they are not representative of the conditions found in a normal turbine bucket with a heavy base and thin trailing edge.

We believe that too little emphasis has been placed on elongation under moderate stress for short periods of time, and we are building new testing facilities to obtain these data.

The effect of aging prior to service, as well as the effect of aging in service, has received very little attention. The investigation of these phenomena and determination of optimum conditions would constitute a large but valuable research program. Some of the considerations involved were covered in the paper presented by Messrs. Badger and Kroft at the 1947 Western Metal Congress which was published in *Metal Progress* in September 1947.

Metallurgical investigation of high-temperature alloys has just barely started. We have pointed out only a few of the items about which additional information is needed. These items constitute major programs on materials currently available and there are many other phases worthy of practical investigation.

In projects sponsored both by Government agencies and private industry, new alloys are constantly being investigated. Up to now, the measuring stick for new materials has been stress-rupture. Yet those experienced in jet engine production or development readily recognize that stress-rupture has been overemphasized, that a great deal of additional laboratory work is needed, and that unfortunately the full evaluation of a material can now be determined only under service conditions.

Fig. 2 — Turbine Bucket for Allison I-40 Jet Engine, as Precision Cast. Blade is 5.45 in. long over all and weighs 16.0 oz.

The materials available at present represent a practical compromise between strength and ductility. They are used now because they can be handled in the shop, because they can be welded, because they can be machined or ground, and because they can be formed (if in sheet or strip).

The metallurgist can now produce stronger materials at a given temperature, or equally strong at higher temperatures, if the mechanical engineer can learn to fabricate and assemble materials with lower ductility. Close cooperation will be required in the years ahead between the metallurgist and the engineer in the development of new and better alloys that can be adapted to gas turbine designs.

Improved Operations at Oak Ridge and Hanford

IN the Fifth Semiannual Report of the United States Atomic Energy Commission to the Congress* especial stress is laid on the fact that "trouble spots which threatened continuity of production of fissionable materials have been largely eliminated. Reorganization, and the addition of new key personnel, has materially strengthened the staff. In 1948 the full program of long-range development got under way. Actual production operations were improved and output increased.

"But there are a number of phases where the rate of progress has not been satisfactory. These include: adequate budget and accounting; cooperation with industrial firms not actually participating in the program; personnel security clearance procedures; recruitment of scientific and technical talent; the issuance and control of information.

"Since the beginning of the atomic energy enterprise in 1939 the American people have invested more than $3 billion in atomic energy, including about $462 millions in fiscal 1948" ($257 millions being operating expenditures and $205 millions for construction). Estimated costs for fiscal 1949 are $353 millions for operations and $279 millions for construction, a total of $632 millions.

Some remarks in a 40-page chapter on Production may be quoted to supplement the official information already printed in the "Smythe Report" and in pages such as these in preceding issues of *Metal Progress*:

Starting with ore concentrates, "the raw feed material, which contains many unwanted chemical elements, goes to chemical refineries to separate a highly purified 'brown oxide' (UO_2). In the past two years there has been an increase in production capacity for brown oxide, and a decrease in costs. Taking 100 as the 1946 level of cost per unit, for 1947 it was 83, and for 1948, 79.

"Next the purified brown oxide is converted into 'green salt' (UF_4), a powder. This stage involves novel chemical processes; the plants, constructed under extreme pressure of war, were not intended to be permanent", and will be replaced as soon as possible. Nevertheless, improvements have been made: "Taking 100 as the cost level for 1946, that for 1947 was 91, and for 1948, 84.

"For use in the gaseous diffusion plant at Oak Ridge, the feed material is converted to UF_6 which, at somewhat elevated temperatures, becomes a gas. During 1947 and 1948, production has increased markedly and costs have declined. Taking the cost level for 1946 as 100, it was 97 for 1947, and 87 for 1948.

"Although much higher standards of purity are required, the atomic industry is not very different from many other refining and chemical industries up to this point, but the porous barriers through which UF_6 is diffused at Oak Ridge are probably unlike anything ever before devised. They must contain billions of holes per square inch, each one a few ten-millionths of an inch in diameter. They must be very thin, yet withstand considerable pressure. The total area is measured in square miles. Barrier manufacture has been a 'batch-type' operation; recent developments have pointed the way for continuous production.

"UF_6 is so reactive it eats through glass. No ordinary pump packing or valve seat can contain it. During the war, a corrosion resistant plastic compound, fluorothene, was developed. Its production by private industry for commercial purposes is now permitted.

"At the outset of production in 1944, some 11,000 workers were employed in the diffusion plant. On Jan. 1, 1947, there were some 7000. Today, although output has been increased, the number of workers is less than 5000. Plant data are continuously and automatically reported by a vast complexity of instruments into a central control room. From it, by motor-operated valves, the flow of the process can be governed.

"In the operations at Hanford, the feed material is reduced to extremely pure uranium metal. To provide additional capacity, the Commission reopened one of the wartime [metallurgical] plants and started construction of a new one to incorporate all the results of five years' experience. With the cost level of 1946 taken as 100, the corresponding level for 1947 was 79, and for 1948, 75.

"'Hanford Engineer Works', as constructed during the war, consisted of three reactors and the necessary chemical separation plants, together with supporting facilities, including plants for 'canning' the uranium slugs in aluminum before they are fed into the reactor. The serious deterioration of the reactors resulting from more than three years of intensive operation required a major overhaul and reconditioning program. Production of plutonium could not be interrupted. Therefore, portions of the repair job were scheduled during each regular shutdown for insertion and discharge of slugs. By mid-1948, the work was completed; production in a given reactor then compared favorably with the highest wartime rate.

"Since a nuclear reactor cannot be 'taken apart for repairs', new reactors are required even to assure maintenance of present output. Schedules, however, call for *increased* production. To provide the additional capacity, a construction program was brought to a peak by more than 15,000 workers.

"Chemical plants to separate plutonium from irradiated slugs of uranium are long, deep canyons of concrete (90,000 cu.yd. for each plant), containing processing cells within which the necessary series of operations can be carried on by remote control. The materials are intensely radioactive; personnel remain behind shields several feet thick and view the work through periscopes. The remaining uranium, contaminated with highly radioactive fission products, is held in storage. In the original design, there was no plan to provide for its recovery. A large aggregation of scientific and engineering talent is now at work on this problem."

*A 200-page book published in January and for sale for 45¢ by Superintendent of Documents, Government Printing Office, Washington 25, D. C.

CARTRIDGE CASE INSPECTION BY REFLECTOGAGE

By Fred M. Arnold
Director of Research and Development
Norris Stamping & Mfg. Co.
Los Angeles

AN article in last month's *Metal Progress* described some troubles encountered at Norris Stamping & Mfg. Co.'s plant in the manufacture of brass cartridge cases (3-in. ammunition for U. S. Navy). The source of the trouble was traced to the melting department of the brass mill which supplied the disks from which these cases were made. The defect itself consisted of internal ruptures in the head, parallel to the base. Figure 1 shows half sections of four such defectives, cut open to reveal the cracks.

As indicated in the preceding article, the defect was first discovered by an inspector who noted a crease on the inner surface of the bottom of the case, and it was first thought to be a mark impressed by a rough-surfaced heading die. We were fortunate in finding, early in the investigation which immediately started, that Sperry Products Co.'s "Reflectogage" was able to reveal these cracks when they existed in metal quite sound as to external surface, and it is our opinion that this method of inspection of cartridge cases is of enough importance to the national defense to be placed on record in the technical and metallurgical literature.

Shortly after the defect had revealed itself we sent a member of our staff, John P. Isaacs, east

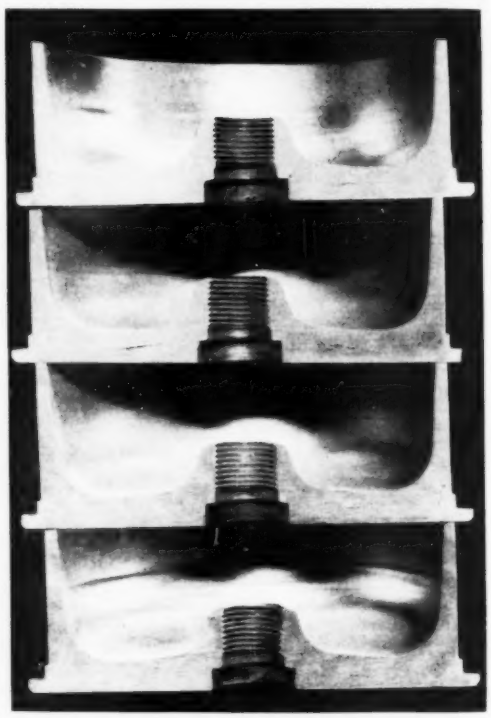


Fig. 1 — Four of the Cases That Were Rejected by the Reflectogage as Having Extensive Cracks in the Head, After Proof-Firing and Sectioning

with some sample cases, both good and bad, to Sperry Products Co. to find out whether that company's "Reflectoscope" could be used for an inspection tool. This instrument was known to us through the literature* and from observation; it starts supersonic waves into the part and then "listens" for echoes from the far surface or from sizable flaws within.

Tests quickly showed that — due to the thin section of the case head — the Reflectoscope could not be used, but that the *Reflectogage* would be able to indicate the presence or absence of internal flaws of some extent therein. The latter instrument was developed to determine the thickness of metal which cannot be measured by other means,

Fig. 2 — Quartz Crystal in Its Mounting

and was especially useful for checking the wall thickness of the blades of hollow steel propellers for aircraft. The principles of its operations are described below. On the evidence of the tests at the manufacturer's plant, we purchased one of these instruments and had it air expressed to us for immediate use to segregate cases with internal ruptures in the head.

Principle of Operation

The operation of the Reflectogage is based on the principle that when high-frequency sound waves are introduced into a material to be measured, the frequency at which the material resonates is directly related to its thickness. This relationship at resonance is $T = \frac{\frac{1}{2} S}{F}$ where F is the frequency, T the thickness in inches, and S the speed of sound (in. per sec.) in the material.

*"The Supersonic Reflectoscope for Interior Inspection", by Floyd A. Firestone, *Metal Progress*, September 1945, p. 505.

Vibrations originate in a variable high frequency oscillator within the instrument which is connected to a quartz crystal. The high-frequency electrical output from the oscillator causes the quartz crystal to vibrate at the same frequency.

The crystal is held against the material and introduces these vibrations into it. When resonance is established the oscillator is disturbed and a vertical peak appears on the trace showing on an oscilloscope screen. A calibrated screen in front of the oscilloscope indicates the thickness of the material under the crystal by the horizontal position of the peak.

There are two possible types of indications which may appear. If the piece, whose thickness is to be measured, is resonated in the fundamental mode, a single vertical peak appears and the thickness is read directly on the calibrated screen. However, if it is resonated in the harmonic mode, more than one peak would occur, indicating that the material is thicker than the maximum reading of the Reflectogage.

A simple calculation then determines the actual thickness of the material.

Use of the Reflectogage as a Flaw Detector

Under certain conditions, the Reflectogage may be used to detect flaws in material. The best results are obtained if the flaws or discontinuities lie parallel with the surface from which the test is made. The method of inspecting for internal soundness is as follows:

The crystal is placed against the material as in checking for thickness, and the thickness points appearing on the oscilloscope (whether single or multiple) are noted. The crystal is then moved over the surface to be explored. If a defect is encountered which is larger in area than the crystal, the original thickness indication on the oscilloscope will disappear entirely and a new indication will take its place which shows the distance from the surface to the defect. If the defect is smaller than the crystal, the vertical height of the original thickness indications will be reduced, depending on the size of the defect.

It is necessary to cut numerous defective samples so as to relate defect size and location to oscilloscope peaks and to establish limits of acceptability. The inspector can then determine if a suspected defect is larger or smaller than some maximum acceptable size.

We applied the Reflectogage in this way to sorting out the defectives from about 75,000 finished cases. The crystal mounting is shown in Fig. 2. An aluminum ring is used to locate the case in the proper relation to the crystal — the

white spot visible in its mounting. When the instrument is connected and no metal is in contact with the quartz crystal, the trace is a slightly wavy line along the horizontal diameter of the oscilloscope screen.

In this setup, every normal cartridge case can be expected to resonate the same because the contour and thickness are substantially fixed. We selected the point where the head is the thinnest to apply the crystal. The mounting was spring loaded and served to insure flat, firm contact of the crystal against the case head. The heads were moistened with diluted glycerin to insure good acoustical contact, placed in the ring against the crystal, and rotated 360°.

Figure 3 shows a case in place; the trace on the cathode ray tube is indicative of a "good" head. This trace is the result of the resonance in a *sound* cartridge case head. The peaks are very high. When moderate defects or even marked coring is present, the peaks are lower, as shown in Fig. 4. Large discontinuities parallel to the surface, such as found in the defective heads of Fig. 1, reduce the height of the peaks further, as shown in Fig. 5. The reduction in height is proportional to the extent of the defect.

All cases which gave traces between Fig. 4 and 5 were rejected and scrapped.

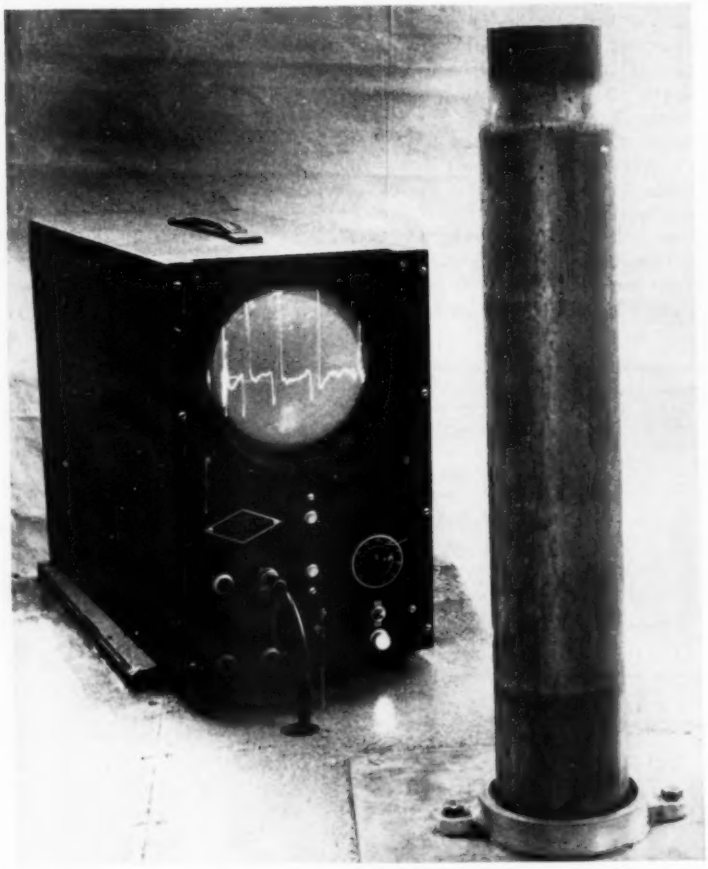


Fig. 3 — Test Assembly, With Cartridge Case in Place. Trace on oscilloscope screen is typical of sound metal in the case's head.

Inspection of Production Lots

Obviously, cases with any internal separation are unacceptable by any standards. When the defect was discovered, there were about 77,000 disks from this source in various stages of completion. All completed lots were segregated and all pieces in process were completed.

Upon the arrival of the Reflectogage, every case was tested and the defective cases were scrapped. Below is a tabulation of inspecting the lots:

Lot	Quantity	Rejects	Per Cent
4	10,000	401	4.0
5	10,000	499	5.0
6	10,000	303	3.0
7	10,000	344	3.4
8	10,000	588	5.9
9	10,000	398	4.0
10	10,000	382	3.3
11	3,676	233	6.4
Total	73,676	3,148	4.3

Ballistic Tests

To gain some knowledge of what would happen if cases with internal defects in the heads were fired, 12 cases which were rejected by the Reflectogage and which gave indications of extensive cracking, and eight cases rejected with indications of minor cracking were sent to the Bureau of Ordnance and were proof-fired. It is perhaps not surprising that all fired and functioned normally and without incident, when it is remembered that the head is well supported by the breech-block and the stress normal to the plane of defects is compression rather than tension. These fired cases have been cut and show cracks present similar to those found in the earliest stages of this investigation. Four examples are shown in Fig. 1.

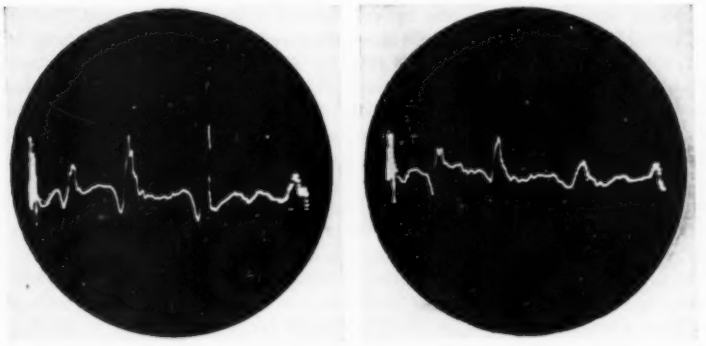


Fig. 4 and 5 — Traces From Heads With Small and Large Defects (Rejection Limits)

CRITICAL POINTS

By the Editor

Powder Metallurgy

AT a well-attended meeting in Pittsburgh of experts in the field of powder metallurgy (the American Society for Testing Materials' Committee B-9) was interested to find some men who *(a)* deplored the industry's penchant for secrecy, *(b)* noted certain indications that fenced plants kept out more information than they locked in, *(c)* recognized definite limitations to the scope of their art and science, and *(d)* were enthusiastic about new developments. The last mentioned is the most normal, and might first be elaborated:

American producers of iron powder have been hit by postwar importations of Swedish sponge iron powder, used for oil-less bearings or mechanical parts. However, there has been a growing demand for electrolytic and carbonyl iron for other applications in which superior characteristics overbalance price — for example, telephonic equipment, "talking tape" for sound recorders, radio devices, and especially television sets. Another intriguing use for iron powder is to boost the temperature of intense flame. Thus, when introduced into a properly adjusted oxy-acetylene blowpipe the flame temperature (already high) is boosted another 1000°; this extra margin is needed to cut the heat-resistant alloys, and the iron oxide in the flame helps flux the refractory chromium oxide which otherwise would effectually stop further combustion. Metal powders even have some possibilities as auxiliary fuel for propelling rockets and guided missiles.

Coming back to earth and noting some limitations of powder metallurgy, they chiefly relate to three aspects — shape and size of parts, size of production run, nature of material. Investment

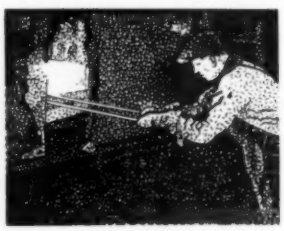
casting is the logical way to make small complicated shapes of high precision; powder compacts must have relatively simple contours. Investment castings can compete even on simple shapes for a moderate sized order; beyond 20,000, more or less, the economic balance is in favor of compacting and sintering. Of course, powder metal technique is essential in the manufacture of many important items of unique properties — "self-lubricating" bearings, filters, nonseizing friction disks, cemented carbides and metal-nonmetal combinations like copper-carbon commutator brushes. Add to this list the working of tantalum and other "infusible" metals, and you have an imposing array of possibilities in fields where there is little or no competition for powder metallurgy.

However, the experts are still baffled by the fact that several common metals cannot be compacted without troublesome binders. For example, powdered white iron is a cheap byproduct of abrasive shot manufacture, but no amount of pressure will make it stick together; it is brittle and just breaks up into smaller fragments. But brittleness is not the entire reason, for neither will soft round copper shot cohere under pressure. Maybe it is shape in this instance; neither can the flaky metal powders produced in great amounts for the paint industry be pressed into useful compacts. But do not jump at conclusions — Madagascar flake graphite compacts beautifully. Is it lack (or presence?) of surface film? Stainless steel and some silver powders compact as poorly as copper shot; however, aluminum (except flake) compacts well!

Such interesting questions as these enliven the days of engineers in the powder metal industry. That scientific, technical, and industrial problems are discussed so freely is evidence that the industry is not only growing, but growing up.

Heat Treat for Tractor Parts

MIDWINTER Minneapolis strutted an exhibit of seasonal weather, subzero temperature masquerading as brilliant sunshine, a cloudy "milder" day (meaning 10 above), and then a ghostly snowstorm — matters the residents take in their fur-booted stride. So to Minneapolis-Moline's plant and was shown foundry and heat treat by Bob Lundquist, supervisor of the metallurgical department. To eke out a shortage in pig iron, cast iron borings (or crushed steel turnings) are briquetted at 25 tons per sq.in. The fine material, without washing or other pretreatment, is squeezed into 4-in. round "bricks", 3 in. high, at the rate of 750 per hr. Both cast iron and steel compact so tightly they stand rough handling. Lundquist says the cupola charge can take 16% without resulting in oxidized iron.



This hydraulic press originally had a cylindrical mold liner of expensive high speed steel; within a week this liner would fail, apparently by fatigue stress at the inner (wearing) surface. Finally a replacement was made with carburized S.A.E. 8620H, which lasted three months; the quenched inner surface is not only excessively hard against wear, but high compressive stresses also result from the heat treatment, and counteract to a considerable extent the bursting stress when each briquette is squeezed, thus keeping the maximum tensile stress within the endurable limit.

Making no more than 100 tractors a day, production at Minneapolis-Moline is not large enough to warrant separate furnace lines for individual parts, so the heat treat is notable for a variety of furnaces, each of generous size (for tractor parts are large and heavy) and capable of handling a wide variety of shapes. The largest is a continuous pusher with three temperature zones for fast isothermal annealing. Much of the hardening is done in a turret furnace 11 ft. in diameter. The adjoining quenching tanks (oil and water) are served by clever mechanisms whereby baskets or cradles, suitable for the parts being quenched, are pivoted by gimbal joints on operating arms, swung out to the center of the tank, and lowered vertically into the quench, returning to their loading position automatically after a measured time interval to be unloaded and reloaded. Circulating quenching fluid is pumped from an underground cooling reservoir and enters the tanks through six feed pipes, three equally spaced on each side, three nozzles on each pipe. The 18 nozzles, pointed toward the tank's axis, give a desirable active circulation. When compared with a quench in still oil, the work can be tempered about 50° F. higher; improved machinability results from the higher draw given the parts.

Included in the furnaces in this well-ordered department are pit-type draw furnaces, batch-type hearths for box carburizing, and induction hardeners, large and small. One interesting homemade device is for flame hardening drive gears, 16-in. diameter with 2¼-in. face. These gears are made of C1038 steel (special specification limiting the residuals and degree of hardenability). In the 4 min. at heat

the ring gear expands enough to drop over a cast iron wheel center, and the spray quench then shrinks it tight. (Too high hardenability means insufficient shrinkage, and a poor hardness contour in the teeth.) After drawing at 375° F. the teeth are C-57 at tip and C-52 to 55 on pitch diameter. Heat is from premixed natural gas and air at 3 lb. pressure; heat treatment is so rapid and flame so "neutral" that no shaving is necessary on the hardened teeth. Lundquist also says that not one field failure of this part, so made, has been reported in the four years this equipment has been used.

An interesting device makes 1000 harrow teeth an hour — formerly forged to sharp point and headed somewhat like a railroad spike. Stock is triangular in cross section (about ¾ in. on a side), cut 10 in. long — enough for two teeth. As it approaches on a link conveyer, each piece is heated at the ends and for 4 in. at the center by gas flames. The heated bar is gripped by two vises at the cold regions and pulled apart, the hot central portion necking down to a sharp point. Immediately, the outer ends are upset by single-stroke dies, the pieces drop into an oil bath, and the job is done. Stock is re-rolled rails; final hardness about C-40.

Success Story

AWAY BACK in 1928 two New Yorkers visited the National Metal Exposition, held that year in Philadelphia, in search of ideas. Their business was to improve dental techniques; in fact, dentists had been sending their tough jobs to these two partners, R. W. Erdle and C. H. Prange, for some years. While so enthusiastic about the possibilities of stainless that they called their business Austenal Laboratories, they knew that these alloys were far from ideal, even though readily workable, for they were ever so slightly soluble in saliva — nevertheless, soluble enough for a distinct taste. Hence they needed a hard overlay of gold alloy, swaged on — a rather expensive procedure.

At the Metal Show they were intrigued by the possibilities of the trade-named Stellite alloys — their good color, chemical inertness and low cost (in terms of gold). However, this only started them off on a lot of work to adapt the lost-wax casting method, commonly used for gold dentures, to the much less fusible cobalt-base alloys, which require quite different mold (or "investment") materials. Also, with cooperation of Haynes Stellite Co., a modified alloy named Vitallium was devised which had the minimum electrode potential of all the cobalt-chromium-tungsten family, meaning that it would be the least soluble in human secretions. Austenal Laboratories' business then became one of promoting the use of this improved dental alloy and the techniques of making the dentures, in which business they were so successful that one day a Texas surgeon, interested in finding a good metal for bone splints, was told by his dentist that he should by all means include Vitallium in his experiments, and gave him some samples. It worked wonderfully well, was hospitable with its surroundings and caused no decay — the common fault of previously used materials.

Surgical items of this sort, which then came into demand, are frequently much larger than dentures, and require a different manufacturing technique. Consequently, Erdle and Prange revised their dental casting procedure and thus laid the foundation for what is now described as "investment molding" or "precision casting". The patterns are of wax; a fine-grained, self-setting investment is then poured around them, the wax is melted out, the mold heated white hot, and the molten alloy forced in under air pressure.

So, when our war planes needed turbine blades for superchargers, and later for gas turbines, the method was ready for making highly precise parts of difficult shape and of refractory metal all but impossible to machine. But one thing turned out to be true that could hardly be predicted — the alloy perfected for resistance to dilute solutions circulating through the body at 100° F. required only minor modifications to become the best material for highly stressed parts operating in hot scouring gas streams at 1500° F. or more.

Railroading Note

IS IT A SIGN that the United States government is gaining dominance over the British that the nationalized railways have decided to replace the standard "bull head" rails with a new design of "flat-bottomed rail", like the American T-rail? Or is it merely that English engineers eventually recognized a good thing? *The Engineer* for Feb. 4, 1949, says that the new 109-lb. rail, which will replace the old 95-lb. bull head rail, "affords greater strength and safety; tests in track since 1936 show they also make for quieter and smoother running and produce economies by reason of their longer life and lower maintenance costs." Each mile of track requires 16,900 fewer components (fastenings, fishplates, baseplates) and therefore about the same tonnage of metal, despite the heavier rail section. The 109-lb. T-rail is 59% stronger vertically and 136% stronger laterally than the 95-lb. bull head it will replace on main line track.

Shall we score one for the Labor government?

BONDING OF STEEL TO CAST ALUMINUM AND USES THEREOF

By C. E. Stevens, Jr.
Chief Engineer, Al-Fin Division
Fairchild Engine & Airplane Corp.
Farmingdale, N. Y.

DURING World War II the aircraft engine industry had to increase the horsepower of air cooled engines to outputs previously thought impossible. This led to many new developments such as turbo-drive supercharging, and automatic manifold pressure control. The one with which Fairchild was particularly concerned, however, was to increase and improve the cooling of the cylinder barrel.

The armed forces were interested in the design possibilities of an engine like the V-12 320-hp. Ranger (Fig. 1) with its small frontal area, but not unless the rating could be increased to 525 hp.

Several necessary components leading to this end, such as increased compression ratio, supercharging, improved cam design, and more efficient carburetion were developed, but it was still confronted by deficient heat transfer of the cylinder barrel.

This problem is the more critical for in-line closely-spaced cylinders, a mark of all Ranger engines. Only the first two cylinders of the V-12 engine receive the same cooling air that *all* the cylinders receive in a single-row radial engine. Even in the twin-row construction of radial engines the second row is staggered with respect to the first, so that cooling the second pair of cylinders on an in-line engine is more difficult than the second row of a twin-row radial engine.

Fairchild then started a project for bonding

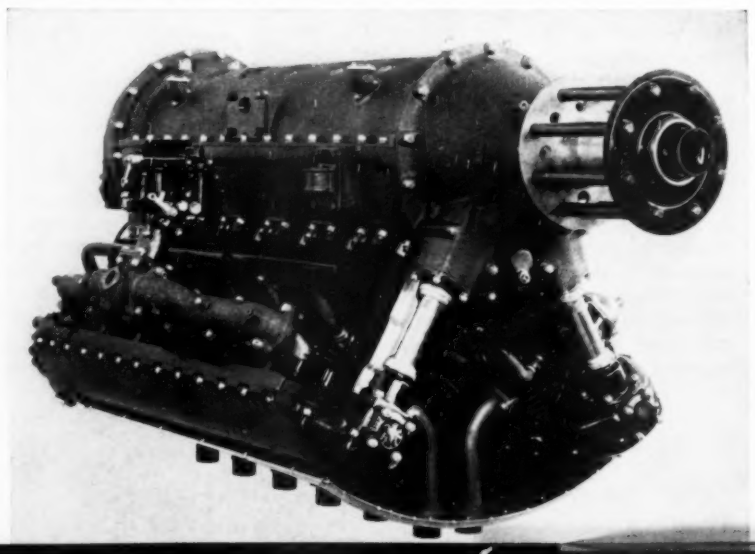


Fig. 1—A Prewar Model of Ranger 320-Hp. Air Cooled Engine, 12 Cylinder, 770 Cu.In., Inverted Vee

aluminum to steel so that the strength of a high-alloy steel cylinder liner could be combined with the excellent heat dissipation from deep aluminum fins. Many years of testing had shown aircraft engineers that an aluminum-finned muff, shrunk or cast on, would not do the job. A chemical bond was necessary for good heat transfer. A mechanical joint, while perhaps 80% efficient when new, deteriorated in use by interface oxidation and even physical separation. This development was successful and led to what is now known as the "Al-Fin process", covered by U. S. patent 2,396,730 and others.

First tests of the heat transfer of cylinder barrels manufactured by this process were on a single-cylinder engine mount, using a standard all-steel cylinder barrel and an Al-Fin bimetallic barrel, both of the same fin dimensions. The tests, run by the Ranger Division in conjunction with the Ethyl Corp., showed better cooling with less cooling air and at lower power for moving the cooling air. Figure 3 gives these comparison values graphically; other related curves show that at 50 indicated hp. per cylinder the all-steel cylinder needed 2760 lb. air per hr. whereas the Al-Fin cylinder needed only 1490 lb.

As a result of this study it was apparent that over 45 hp. per 64-cu.in. cylinder was impracticable with steel construction, but that up to 700 brake hp. might be ultimately expected from the V-12 engine using Al-Fin barrels. Another improvement noted was in piston ring life, due to the cooler cylinder walls.

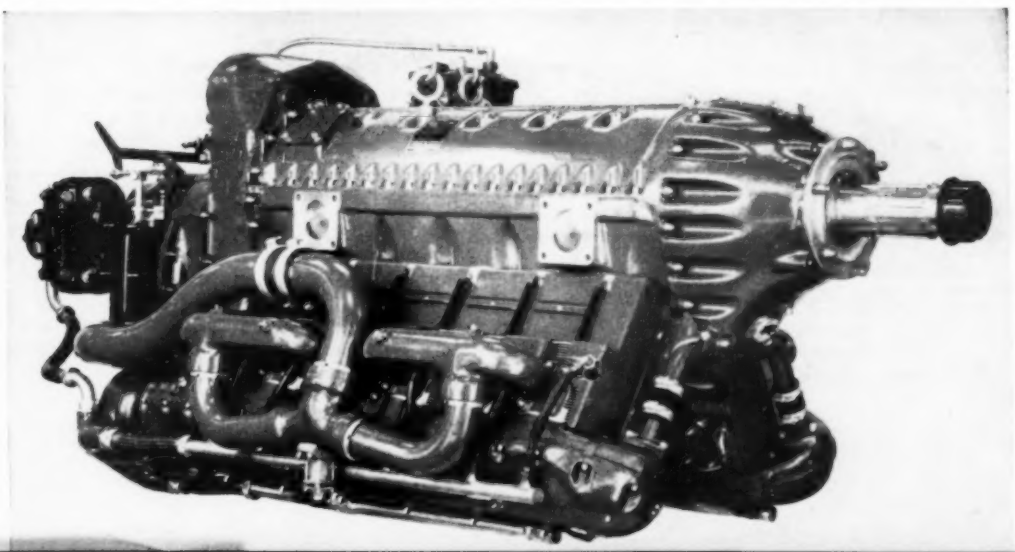
In the development as a whole, many aspects had to be considered besides the actual bonding of the two metals. First, there was the stress behavior of a bimetallic assembly in which the coefficients of thermal expansions are different by a factor on the order of two (4140X steel = 6.22×10^{-6}; aluminum alloys, about 12.2×10^{-6}). Second, what effect would the processing have on the strength and fatigue properties of the steel? Third, was some new factor introduced into the theory of fin design by the change in thermal conductivity of the fins themselves?

Table I — Effect of Al-Fin Processing on S.A.E. 4140X Steel

Property	Steel (Unprocessed)	Steel (Al-Fin Processed)
Rockwell hardness	C-33.0	C-32.0
Tensile strength	148,000 psi.	147,500 psi.
Yield point	143,000 psi.	139,000 psi.
Elongation	18%	23.5%
Reduction of area	55%	63.8%
Izod impact	51.5 ft-lb.	76.7 ft-lb.
Endurance limit	70,500 psi.	54,000 psi.

The first of the above problems was solved by a mathematical analysis in conjunction with laboratory testing, and a design worked out which would withstand temperatures of 800° F. without impairing the bond. In like manner a program of testing indicated certain improvements in manufacturing routine so that heat treated alloy steel cylinder liners could be processed without reducing the resistance to wear (Table I). Fatigue strength, however, was slightly impaired, an obvious result of the solvent action of molten aluminum on polished steel. For the fatigue tests,

Fig. 2 — Wartime Model of Ranger 700-Hp. Air Cooled Engine, 12 Cylinder, 770 Cu.In., Inverted Vee (SGV-770-D1)



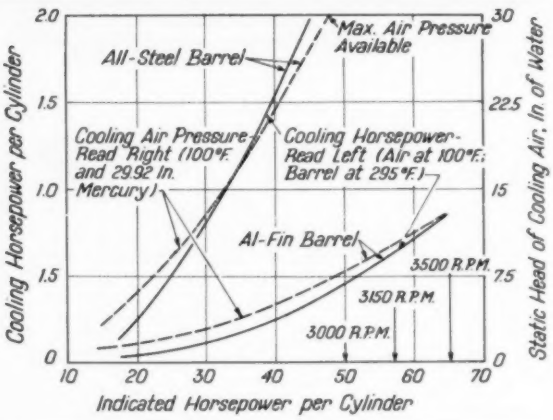


Fig. 3 — Data From Test Engine on Cooling Air Required for Steel and Al-Fin Cylinders

R. R. Moore test pieces were aluminum coated and run alongside standard polished steel specimens. The steel in both was S.A.E. 4140X, the standard Ranger cylinder barrel alloy. These physical tests indicated that the wall thickness of the liner should be increased by only 3.4%.

The third problem required a comprehensive study of fin design and a new system of baffle location and engine installation arrangements so as to take full advantage of the new bimetallic barrel.* The shrouds to be seen around the cylinder barrels in Fig. 2 are of utmost importance, as well as self-adjusting gills in a large opening in the nacelle immediately ahead of the engine, directly in the propeller blast.

The hoped-for goal of this, the first and motivating development for which the Al-Fin process was conceived, came when the SGV-770-D1 engine (Fig. 2) was successfully tested at 700 brake hp., thus realizing the full possibilities of the tests on a single-cylinder engine.

Description of Process

Suitably cleaned steel or iron parts, designed to serve as liners or inserts or members in a proposed bimetallic casting, are first immersed in molten aluminum. A necessary condition for a bonded metallic coating is that the material to be coated be soluble in the molten coating material. This condition is met; aluminum attacks the surface of the steel or iron and forms an alloy of iron in aluminum. If this coated surface, while hot, is abraded, one cannot scratch off this coating, just as it is impossible to scratch-remove hot solder from a piece of adequately tinned copper.

When the insert is so coated, the first step in the Al-Fin process, it is promptly placed in a sand or permanent mold; the mold is quickly closed and poured while the aluminum on the surface of the insert is still molten.

Since the average bonding temperature is in the range of 1300 to 1450° F., the alloy formed will be primarily $FeAl_3$. Consideration of the binary phase diagram, shown on p. 1161 of ⊜ "Metals Handbook", bears this out. Because the temperature of the process is low, reactions are confined first to the aluminum-rich end of the phase diagram. Assuming minimum bonding time, the probable analysis of the alloy formed on the ferrous insert will be 59.4% aluminum, namely, the intermetallic compound $FeAl_3$.

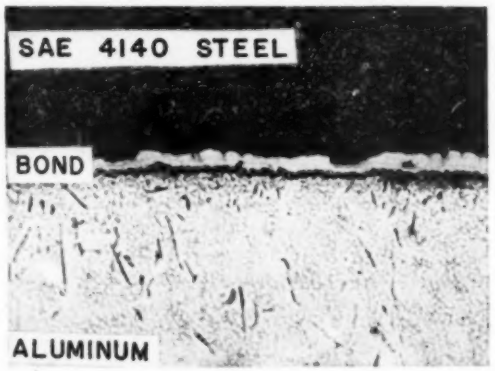


Fig. 4 — Bond Between S.A.E. 4140 and Aluminum Alloy (250 ×)

This $FeAl_3$ layer, or bond, is shown in Fig. 4. Evidence of the attack on the steel by the molten aluminum is clearly shown in the form of inlets or bays at the shore line.

*See "Factors Pertaining to the Installation of Inverted, In-Line, Air Cooled Aircraft Engines", by T. F. Hammen, Jr., and W. H. Rowley, *S.A.E. Journal (Transactions)*, V. 54, March 1946, p. 138. "Design Information for Optimum Heat Transfer From Fins", by F. A. Hiersch, Al-Fin Technical Report, 1946.

In improving a V-12 in-line airplane engine, Fairchild Engine and Airplane Corp. found that a steel cylinder liner chemically bonded to aluminum exterior fins had vastly better heat transfer than the conventional finned steel (integral) construction. Bimetallic casting techniques are briefly described in this article, as well as properties of the joint. The process, dubbed "Al-Fin", has been extended successfully to the manufacture of brake drums and power-tube radiators, to aluminum gearing with steel hubs, and to steel-backed bearings.

It is possible, upon further heating or holding at bonding temperatures, to cause diffusion toward the iron-rich end of the phase diagram. As this tends to increase the bond thickness, however, this prolonged heating is avoided as much as possible.

The physical properties of the bond must be known in order to design bimetallic castings. The observable bond is composed almost entirely of the intermetallic compounds of iron and aluminum, extremely high in hardness and almost equally low in ductility. (The microhardness is on the order of 875 Vickers diamond Brinell.) Ordinarily, high hardness is associated with high tensile strength, but when ductility is very low it is difficult to obtain a true tensile strength. Obviously, it is to advantage to control the factors of production so as to keep the bond thickness to a minimum. In bonding aluminum to steel, 0.001 in. is the usual maximum, and there is advantage in keeping below this limit. (The bond shown in Fig. 4 is about 0.0004 in. thick.)

In tensile testing the bond an attempt is made to follow actual use of the bond and thus obtain valid data. In practice, design dictates that the ferrous piece be partially imbedded in the aluminum structure. The testing technique developed, therefore, follows this practice.

A ferrous specimen is machined as shown at the left in Fig. 5, bonded over the surface of the tenon at the small end, and cast as shown dotted at the right. Any heat treatment called for by the aluminum alloy specification is performed at this stage. The bonded and cast piece is machined to the final form shown in Fig. 6. The sample is then pulled in a standard tensile machine.

Fracture will occur in the plane of the bond face, showing a clean fracture normal to the axis. The thin shell of cast aluminum surrounding the large bonded face breaks in the same approximate plane. Companion tests of pieces cast full length and diameter and machined to standard dimensions establish the unit tensile strength T_A of the annular shell surrounding the bond. The tensile strength of the bond is computed from the formula

$$T_B = \frac{W - A_s T_A}{A_B}$$

Where W = The breaking load indicated on the tensile testing machine
A_B = Large bonded area (end of tenon)
A_s = Cross-sectional area of the aluminum shell (annulus)
T_A = Unit tensile strength of the aluminum alloy.

Tests carried out on bimetallic samples made with steel, and using this technique, show a bond strength of from 11,000 to 17,500 psi., varying more with bond thickness and aluminum analysis than with steel analysis. With cast iron the tests show from 8500 to 12,000 psi., bond thickness being more difficult to control with coarser microstructures.

Tests run at temperatures up to 500° F. show no reduction in bond strength.

Samples, cast at the same time with all factors held as constant as possible, agree within 10%. It is quite probable that the test results are on the low side of the true bond strength. Keeping in mind the fact that we are dealing with a material of almost zero ductility, it is clear that a minute point of fracture on any edge will produce a concentration of stress that will cause instantaneous failure over the entire bonded surface. When

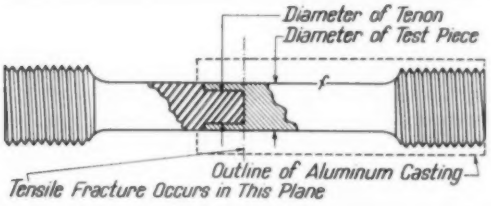


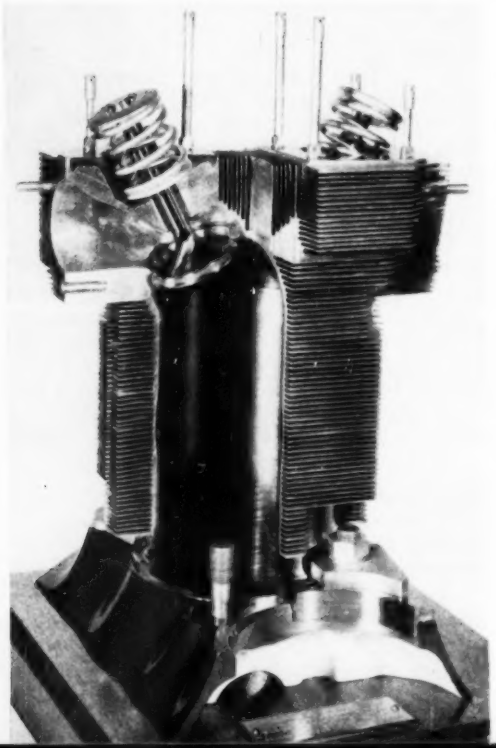
Fig. 5 — Test Piece for Measuring Tensile Strength of Bond, Aluminum to Iron or Steel

comparing the strength of a bond of minimum thickness against the *yield* strength of the aluminum alloy bonded, there was a parallel. The tensile strength of the bond at room temperature was within 1000 psi. of the yield strength of the sand casting. At elevated temperatures, it is believed that the increased ductility in the specimen gives a more uniform stress distribution, and a smaller tendency to point stress concentration.

Values for shear strength are also difficult to obtain in a conventional manner because of the character of the bond. In our techniques we prepare small cylindrical inserts, finish the surface to 10 micro-inches, and cast them into the center of aluminum disks. Such shear test pieces are always prepared in pairs, one with the insert bonded, the other with the insert cast-in, but not bonded. (The latter sample is heated to bonding temperature before being placed in the mold.)

The inserts, in testing twins, are then pushed out on a hydraulic press and the total force noted. The difference in applied force, divided by the bonded area, gives the unit shear. Shear values thus obtained run from 7000 to 9000 psi., depending upon the aluminum alloys used. In one particular test, before a skeptical audience, an unbonded hub, 3 in. diameter by 1 in. thick, was pushed out by a force of 4250 lb.; the identical bonded insert required a force of 76,840 lb.

Fig. 6 — Ranger Unit Cylinder, Developing Nearly 1 Hp. per Cu.In. of Volume, Sectioned to Show Bimetallic Construction



The bond thus obtained is pressure-tight against 1000 psi. of dry nitrogen, and S.A.E. No. 10 oil at 60 psi. and 100° F. While the heat conductivity and electrical conductivity of the $FeAl_3$ compound is undoubtedly quite low, tests by Prof. Carl F. Kayan at Columbia University and in our own laboratories have been unable to measure any temperature drop or voltage drop across the very minute bond thicknesses. Designers, then, may neglect the bond when figuring the thermal or electrical conductivity of such bimetallic construction.

Recent Development Work

The first development was in the design of aircraft cylinder barrels. Ranger engineers went on to a logical next step in developing a unit-type cylinder wherein not only the walls are of steel bonded to aluminum, but the whole dome as well. In Fig. 6 it will be seen that a thin alloy steel shell defines the entire cylinder interior, immediately surrounded by the aluminum finned structure. On test, this 77-cu.in. displacement cylinder developed 85 indicated hp. at 3500 r.p.m., or better than one indicated horsepower per cubic inch — certainly an excellent output for an in-line air cooled engine cylinder. In the original Al-Fin cylinder the upper end of the bimetallic barrel was screwed into a cast aluminum cylinder head. This gave a heavy section in the top ring-travel area; in the design illustrated, the cooling potential in the upper area is greatly increased by the unit cylinder design, thus further increasing piston ring life.

Concurrently, other engine manufacturers, both here and abroad, were studying this construction. Recently, Continental Motors Corp. announced a line of heavy-duty, in-line air cooled engines ranging from 125 to 1040 horsepower for ordnance vehicles, all utilizing Al-Fin bimetallic cylinder barrels. As an example of the saving in weight, the 250-hp. air cooled engine for tank or truck weighs only 777 lb. as compared with 2400 lb. for a liquid cooled engine of the same horsepower.

Another use, that is to some extent an offshoot of the cylinder barrel improvement, is the current development of brake drums. The temperatures which this part has to withstand (1000 to 1100° F.) are greatly in excess of those found in a cylinder barrel. With the cooperation of the Aluminum Co. of America, the formula for a special alloy was worked out for a finned construction chemically bonded to cast iron brake drum liners. The design

was first tested in the laboratory by hundreds of heating-cooling cycles, and then in the dynamometer to see if it would withstand combined physical and thermal stresses. Finally, the brake drums were installed on a 1500-cc. midget racing car, and performed successfully. This test was interesting since no other brake had performed adequately; after a very few laps the brakes would "fade", due to heat; the wear would require brake lining adjustments after every race and replacements every week. The Al-Fin drums stood up without serious wear for the entire 1948 summer racing season. Fading was not a factor, even in 100-lap championship races. Two automotive parts manufacturers now have these drums on proving grounds and road test with no indications of bond failure and every indication of reduced fading and improved life of brake linings.

Another development that is an extension of the heat exchanger application is shown in Fig. 7, a power tube cooling radiator. Here again the stress problem was difficult. The radiator consists of a thin steel liner bonded to the inner diameter of an aluminum core of heavy cross section; this bimetallic part is then jigged with the stamped fins, and furnace-brazed. Brazing temperature is 1075° F.; the fin assembly is 15½ in. tall by 14 in. diameter. (The reason for a steel liner is that it is impractical to sweat the copper anode into an all-aluminum construction, whereas it is simple and inexpensive to solder the anode to the steel core of the bimetallic construction.) In the size shown in Fig. 7, the aluminum radiator weighs 56 lb.; the copper radiator it replaces weighed 186 lb.

In this construction, it can be seen that the stress problem is the reverse of that for cylinder barrels and brake drums. In the latter two the ferrous material was strong and the aluminum weak — that is to say, it was necessary to design an aluminum cross section that was weaker than the bond strength at operating temperature and so avoid failure from thermally induced stresses. On the other hand, a strong aluminum structure about a weak steel cross section, such as the power

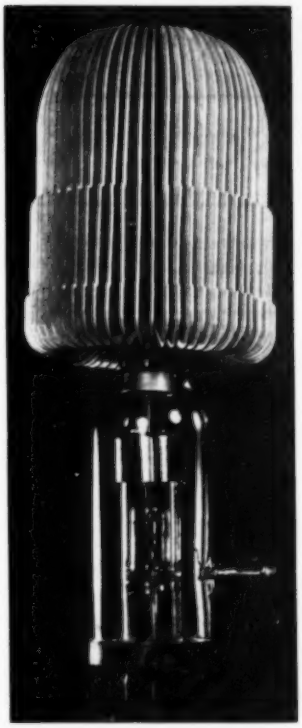


Fig. 7 — Aluminum Finned Radiator on Anode of 4000-Watt Tube, Bonded to Hollow Steel Liner, the Latter Soldered to Copper Anode. Radiator is 14 in. diameter

tube radiator, was finally designed by regulating the cooling speed after the brazing operation, so that the steel was aided in maintaining the bond by controlling the direction of heat flow.

A third successful development, now in extensive commercial use, is the aluminum gear with bonded-in steel hub. One such gear is installed as original timing gear equipment by one of this country's largest truck manufacturers. Unlike the previous applications, this has nothing to do with heat transfer. It was not possible to use an all-aluminum timing gear because of the interference press-on fit required on the camshaft. (Design engineers know of many cases where a shaft hole, a bearing cage, or an oil seal stands in the way of replacing a cast-steel or cast-iron part with aluminum.) Unlike the usual cast-in insert, the bonded insert is rigidly, homogeneously held; it is vibration proof and leak proof, both to hot oil and diatomic gas molecules under high pressures. Possibly this field, rather than the heat exchanger field, will become the most important.

Also in the late stages of development is the steel-backed aluminum bearing. A very comprehensive report by the research division of Gulf Research and Development Co. showed that aluminum alloy bearings alone could be loaded to 7000 psi. without an increase in the coefficient of friction. In gross load-carrying qualities, the solid aluminum bearing is surpassed only by silver plus a lead-indium overlay, or a copper-lead bearing with a lead-indium overlay. By making a steel-backed aluminum or aluminum alloy bearing, the load-carrying qualities are so increased as to compare favorably in this respect with the above bearing alloys. On test, steel-backed aluminum bearings with a lead-indium overlay have performed equally well with steel-backed silver bearings similarly plated, obviously at a lower cost per bearing.

EASTERNERS INVADE SAN FRANCISCO TO TALK METALLURGY

Special Report to Metal Progress

THE 168TH general meeting of the American Institute of Mining and Metallurgical Engineers was held the week of Feb. 13 in San Francisco. This was the first time the annual meeting had been held in San Francisco and if this reporter's information is correct, the second time that this event had been held away from New York City. As a Californian, it is proper to mention that the weather during the meeting was excellent, with only one day marred by a drizzle. For the most part, members moved about town unencumbered by those heavy coats which we assume, from newspaper reports of recurring blizzards in the northern states, must be worn by less fortunate Americans.

Engineering Education

First sessions to get underway were those of the Mineral Industry Education Division, held Sunday and Monday at the University of California in Berkeley, on the theme: "Mineral Engineering Education of the Future in Light of Present Day Research Problems". Although few of the papers would stand a critical comparison of topic and subject matter, the attendance and discussion indicated that there were many who were interested in the trends in education.

Several speakers emphasized the old, old proposition that undergraduates should be well grounded in the fundamentals of basic science and engineering subjects rather than specializing in a restricted part of the field. Graduate work, on the other hand, should be rather specialized. The value of personal contacts was emphasized — the idea of being able to get along with people. (This last point was illustrated in one or two of the sessions at this convention where the authors and active participants showed some reluctance to give full information to people who themselves make a habit of not trading information. The increasing success of technical conventions and the advance of science generally are obviously based on the free interchange of ideas; very soon one learns that his success is limited without it.)

Meetings were held by 13 divisions of this much subdivided Institute, in addition to the Institute of Metals and Iron and Steel divisions. They include the fields of mineral economics, extraction and beneficiation, mining, coal, petroleum, geology and geophysics. About 240 papers were presented in all — a figure that lends some opportunity to the statistical-minded. It is interesting to note that of these, 80% were from industry and 20% from educational institutions. The contributions of the Extractive Metallurgy, Institute of Metals and Iron and Steel divisions totaled 83 papers, of which 65% were from industry and 35% were from educational institutions. Most of the industrial papers were along practical research lines, while most of the papers from educational sources were more theoretical. Especially in the Extractive Metallurgy Division the discussions concerned plant processes.

The above trend is reflected by the attitude of people in educational research. They feel that the theoretical research is better done at colleges and universities where there is usually a wider range of equipment available. This is again reflected by the type of students that are now being graduated from our institutions of higher learning. Here is not the place to argue the problem, but it would be well for faculties to think seriously about the undoubted fact that men in industry have indicated in many ways they do not like the situation wherein the students' education is limited to areas within the instructor's small fields of interest.

Lectures and Awards

The Institute of Metals Division lecture was presented this year by Egon Orowan, who comes from the Cavendish Laboratory, Cambridge, England. Dr. Orowan's lecture was on the "Structure of the Cold Worked Metal". The able presentation and Dr. Orowan's active participation in many discussions of the technical papers showed him to be one of the present day's brilliant scientists. It was a pleasure to have had the opportunity to hear him. One might well say that what an American technical session needs to give it life is a handful of Englishmen!

The 26th Howe Memorial Lecture was given by John Chipman, head of the department of metallurgy of Massachusetts Institute of Technology. The title of his talk, "What Is Metallurgy?", aroused much curiosity; many who came to hear a description of the arts of metallurgy were slightly disappointed. Dr. Chipman's talk hinged around the educational side, rounding out the answer to his question title by showing the component parts of the various metallurgical fields. In this he brought out many of the points in his article in *Metal Progress* for August 1948.

From among the awards, the following fell within metallurgical interest:

James Douglas Medal in recognition of distinguished achievement in nonferrous metallurgy to William Wraith, for many years an executive of Anaconda Copper Mining Co., "for conspicuous leadership in and fundamental contribution to technologic progress in the arts of beneficiating ores of nonferrous metals, especially those of copper".

Robert W. Hunt Award and the Rossiter W. Raymond Award to Michael Tenenbaum of Inland Steel Co. for his paper entitled "Structure, Segregation, and Solidification of Semikilled Steel Ingots".

The Institute of Metals Division Annual Award to E. A. Gulbransen of Westinghouse Research Laboratories and J. W. Hickman (posthumously) for their paper entitled "Electron Diffraction Study of Oxide Films on Iron, Cobalt, Nickel, Copper and Chromium".

J. E. Johnson, Jr., Award to John Daniel Saussaman for his paper entitled "Sinter Practice, Kaiser Co., Inc., Fontana, Calif.".

Grain Boundaries and Surfaces

In the first of the three papers read at the Institute of Metals' session on "Grain Boundaries and Surfaces", C. G. Dunn, research physicist for General Electric, outlined the method used in producing crystals of predetermined orientation, and presented a curve derived in the study of relative surface tension as a function of the difference in orientation. In the ensuing discussion, similar work by A. J. Shaler of Massachusetts Institute of Technology, and his instrumentation and theories regarding the surface tension as related to the gaseous interface were mentioned. Future work on grain-boundary energy was forecast, giving attention to purity of metals and atmospheres.

The paper on "stress-corrosion cracking" by D. H. Thompson and W. Tracy of American Brass Co. showed that the addition of alloying elements (except zinc) to copper produced a minimum breaking time under a tensile loading in a moist ammoniacal atmosphere. This they would attribute to an anodic concentration of the element at the grain boundaries. E. H. Dix, Jr., chief metallurgist of Aluminum Co. of America, endorsed this conclusion, which also embodied the concepts of "stress-corrosion" without stress, diffusion rate of dissolved elements, and increase of transcrystalline fracture with increased work hardening.

E. A. Gulbransen read the paper his associate, the late J. W. Hickman, had written on "X-Ray Diffraction Study of Oxide Films". This investigator found that thermodynamics would not predict the type of oxide that would form on various alloys either as to crystalline form or as to the component metal. In discussion, S. E. Maddigan, director of British Columbia's Industrial and Scientific Research Council, presented a concept of the interaction of crystal geometry and free energy in influencing transformations when thicker oxide films formed. Some members of the audience also questioned whether the authors were correct in considering tungsten-copper and tungsten-chromium mixtures as "alloys".

Plastic Deformation

A session was given over to the consideration of plastic deformation in metals and temper brittleness. A. W. McReynolds, research associate in physics at the Institute for the Study of Metals, University of Chicago, described in detail the phe-

nomenon of plastic deformation waves in aluminum. Aluminum alloys were stretched in a special dead-weight type of tensile testing machine. Effects of structure, chemical composition, rate of propagation, temperature, aging, and heat treatment were determined for commercial 2S alloys and high-purity aluminum-copper alloys. The results enabled him to propose a mechanism for the observed "stairstep" stress-strain curve.

A. N. Holden and J. H. Hollomon of General Electric's research laboratory carburized (and nitrided) single iron crystals in an effort to determine whether or not these two elements had any effect upon inhomogeneous yielding. They verified the findings of Low and Gensamer that carbon or nitrogen caused inhomogeneous yielding in iron polycrystals, but neither carbon nor nitrogen appeared to cause inhomogeneous yielding in iron crystals made from aluminum-killed steels.

The effect of previous strain and temperature (the history) of an annealed steel on its flow and fracture characteristics was investigated by E. J. Ripling and George Sachs in some work done in the research laboratory for mechanical metallurgy at Case Institute of Technology. Their work reveals a few of the laws which govern the mechanical properties of a ferrous metal subjected to straining under conditions of varying temperature. It was clearly shown that no predictions can be made from tests carried out at a constant temperature on the behavior of the same metal when the temperature varies during straining.

As to that perennial problem of temper brittleness, some observations on plain carbon steels by L. D. Jaffe and D. C. Buffum of Watertown Arsenal Laboratory suggest that they also are susceptible and the authors think that temper brittleness develops so rapidly in such steels that even severe quenching from a high tempering temperature is unable to suppress it. It apparently has been there all the time, masking the properties that such ductile metal might otherwise have. (For an abstract of paper see p. 410 of this issue.)

Grain Growth

Some of the more recently investigated factors affecting the grain growth of metals were presented by J. E. Burke, associate professor, Institute for the Study of Metals. Interfacial energy of the grain boundaries rather than the differences in the lattice energy seems to be responsible for grain growth. Dr. Burke surmised that the presence, distribution, and changes in distribution of the impurities were of importance in controlling the rate of grain growth, the maximum grain size, and the temperature effects. In a discussion which followed, the point was raised that some grain growth does not follow the "normal" pattern. It was suggested that such behavior was probably due to the strains within the grain; the strain energy was then added to the driving force.

A. Smigelskas of Argonne National Laboratory and C. S. Barrett of the Institute for the Study of Metals plotted a number of pole figures in studying the deformation and recrystallization orientations of beryllium. Their work included not only samples rolled at room temperature, but some rolled at elevated temperatures; it is significant that at the higher temperatures, no pronounced alteration of the mechanism of crystallographic deformation was observed. However, it cannot be definitely assumed on this evidence that the deformation mechanism is the same at all temperatures. During the discussion which followed, J. T. Norton of Massachusetts Institute of Technology described a rapid method of obtaining pole figures through the use of a Geiger counter.

Pole figures and glancing photograms were used by Ming-Kao Yen of Chase Brass and Copper Co. in investigating the specific influence of phosphorus and other impurities on the recrystallization textures and deep drawing properties of copper strip, especially the "earing" behavior of five types of commercial coppers. Of particular interest was the relation between the contour of the ears on cups and the rolling direction. For a wide range of annealing temperature it was found that the type and degree of preferred orientation were the most significant factors controlling the height and position of the ears. Larger grains will usually promote a tendency toward a preferred orientation, which in turn produces higher ears.

Powder Metallurgy

At the powder metallurgy meeting the use of the resistance type of strain gages to measure the pressure on the stationary elements of dies used in compressing metal powders was reported by Pol Duwez of California Institute of Technology. His data, along with others obtained when using a lead grid for determining the pressure distribution *within* the compact (the method of John Wulff of Massachusetts Institute of Technology) gave a good picture of the present status of knowledge on this branch of the subject.

Experiments on the diffusion of alloying elements in powder compacts were reported in two papers. W. Rostoker of Birmingham University (England) used a magnetic method (checked by X-rays) to follow the changes in the configuration of the voids in the compact and to follow the progress of the diffusion of silicon in iron.

His method for checking results incited a very enlightening discussion by John T. Norton, F. N. Rhines and Egon Orowan, in which was pointed out the possibility of obtaining detailed information concerning the process of diffusion from the variation of density in the X-ray patterns. G. C. Kuczynski of Sylvania Electric Products used a metallographic method to follow the progress of self-diffusion in the sintering of metallic particles, which bypasses the need for radioactive tracers.

A paper presented by H. Udin and his faculty supervisors at Massachusetts Institute of Technology highlighted the symposium on sintering. They developed a method of determining the surface tension of solid metals; data for copper were presented. The lengthy and involved discussion that followed was topped off by F. N. Rhines when he hailed the paper as a landmark in the study of the solid state.

A lively discussion followed the reading by Prof. A. J. Shaler of Massachusetts Institute of Technology of his paper on the "Kinetics of Sintering". Written comments on his calculation methods, forwarded by English metallurgists, were followed by discussions by Dr. Busch of Mallory Company, F. N. Rhines of Carnegie Institute of Technology, and G. C. Kuczynski of Sylvania Electric Products.

All these men agreed that compacts had voids, but ideas as to their size, shape, growth, or movement seemed as variant as the experimental methods chosen for studying the problem of sintering.

Iron and Steel Division Discusses Steel Refining

Further study of the relation between chromium and carbon in the refining of chromium steel was made by D. C. Hilty, research metallurgist at Union Carbide and Carbon Research Laboratory. The bath was rapidly decarburized with a jet of oxygen, producing higher temperatures in the metal. It retained a greater amount of chromium under these conditions. It has long been desirable to establish a real basis for predicting the effectiveness of any operating practice to oxidize the maximum amount of carbon with a minimum loss of chromium. At constant temperature, the relation between carbon and chromium can be expressed by the equilibrium constant $K = \%\ Cr \div \%\ C$. For conditions where temperature is not constant, the effect of temperature on the relation is given by the equation

$$\log K = -15{,}200/T + 9.46$$

C. E. Sims of Battelle Memorial Institute commented on the fact that Hilty's experiments brought out one significant point: Reactions in a steel bath are homogeneous reactions, and the equilibrium conditions established are established within the bath itself.

Extensive investigation by C. E. Sims, G. A. Moore, and D. W. Williams of Battelle Memorial Institute of the effect of hydrogen on the ductility of cast steels further verifies the now generally accepted theory for the mechanism of hydrogen embrittlement. The writers reported that the abnormal loss of ductility caused by hydrogen can be completely eliminated by aging at a moderate temperature for sufficient time to remove the majority of the hydrogen. The temporary loss of ductility while hydrogen is present in the metallic structure is entirely independent of other mechanisms causing *permanent* loss of ductility, such as film formation or eutectic inclusions. Only a very small amount of hydrogen is necessary to reduce ductility to a limiting value of 15 to 30% of the ductility possible in hydrogen-free steel.

In a series of experiments carried out at the Soderfors Steel Works, Axel Hultgren, professor of metallography at the Institute of Technology, Stockholm, Sweden, investigated the conditions for the formation of silicate inclusions in molten steel during tapping and pouring. Turbulence in the tapping stream causes much more oxidation of the metal than occurs in smooth tapping, with the result that larger and *(Continued on p. 390)*

The Mining Engineers' annual meeting, true to form, presented many papers on the smelting of nonferrous metals (these being largely descriptions of plants, improved operations or equipment), on smelting of pig iron and refining of steel (often of the nature of applied research), and on physical metallurgy (principally scientific investigations of nonferrous metals and their alloys). Among the topics of "practical" interest are a study of mill practices on copper strip which are responsible for ears on deep-drawn cups, operating techniques in steel refining for the recovery of chromium in the charge, and the partition of sulphur between metal and slag in blast furnace and openhearth.

DISTINGUISHED METALLURGISTS

SEVENTY-FIVE American and Canadian engineers, metallurgists, business men (some 50 different titles are in the roster) were honored at the last ⊕ Convention for their unusual and meritorious contributions to progress in alloy steel. In the following pages are brief biographies of eight of them. *Metal Progress* will continue the pleasant task, started last month, of honoring these leaders in the metallurgical industry until the list is completed.

John L. Cox

FIFTY-NINE years of continuous service with a single establishment are evidences of continuing success, but the work now acclaimed occurred comparatively early in that period.

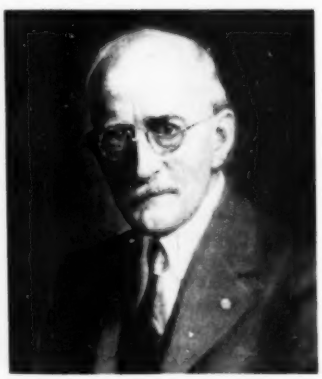
Shortly after graduating from Stevens Institute of Technology as Mechanical Engineer, in 1887, Cox began his career at the Midvale Steel Works as assistant foreman of the forge shop.

In 1899 he spent several months in England acquiring the art of forging under the hydraulic press Whitworth was building for Midvale, and in 1903, when Midvale entered the ship's armorplate field, he directed that manufacture.

The successful delivery of plate to the U. S., and to Italy for the cruiser San Marco, caused the Krupp firm, of Germany, to bring suit against Midvale for alleged patent infringement — which suit Krupp lost, along with its world-wide monopoly! Midvale's armor plate equipment also started American production of the largest sizes of seamless pressure vessels, heavy hydraulic cylinders and turbine shafts.

In 1892 Midvale had begun the manufacture of chromium steel armor-piercing projectiles by the Holtzer process. In 1911, when these projectiles failed to meet the increasingly severe specifications of the U. S. Navy, the projectile plant was reorganized and JOHN COX put in charge of the technical manufacture. He developed new designs, new alloys, new methods of treatment — with marked success.

In the development of armor and projectiles the effect of numerous alloying elements was studied, many combinations made and tested. Some showed such excellent physical properties that they were introduced for commercial use, especially for automobiles. Several of these, with slight changes in the proportion of some of the elements, remain today regular members of the standard S.A.E. and A.I.S.I. series.



John Lyman Cox

Chief Engineer (Retired)
The Midvale Company
Philadelphia

Citation "for early adaptation of alloy steels for armor and projectiles to industrial purposes"

Harry W. McQuaid

Steel Consultant
Cleveland

Citation "for distinguishing between abnormal and normal steels and interpreting the relationship between grain size and hardening properties"

A BIOGRAPHICAL sketch of HARRY WINCHESTER MCQUAID was printed in *Metal Progress* for January 1939, celebrating his receipt of the Sauveur Achievement Award. There is little to add to that account in this place. A graduate mechanical engineer from Stevens Institute of Technology, MCQUAID went to the Timken Roller Bearing Co., working successively as a heat treat foreman, electric furnace melter, and chief metallurgist. For 12 years (1934 to 1946) he was assistant chief metallurgist of Republic Steel Corp. Such an experience is almost unique in the manufacture and treatment of alloy steels and in the design of parts for severe duty.

From a life rich in technical achievements one can dwell only upon one or two, and those the most prolific in the sense of snow-balling

a long chain of associated developments. First would be HARRY's early observations about the interrelation between hardenability and steelmaking practice (1919) which developed the carburizing test later known as the McQuaid-Ehn test. Some steels were "normal", others "abnormal". The carburizing test was originally used to separate melts of carbon steel intended for case hardened parts according to their hardenability, but now is widely used for all grades of steels.

If anyone were to say that new ideas are immediately accepted in American metallurgical circles without critical discussion he would be judged to be seriously ill-informed. In this, the argumentative "normality" and "abnormality" was no exception. The basic central theme was confirmed by many investigators while the significance and explanation of the observations became a subject of a plentiful amount of good, healthy, scientific controversy. Many are the brilliant researches prompted at least in part by MCQUAID's publications.

The Distinguished Service Award is intended to reward, particularly, those pioneer achievements which have had outstanding subsequent effect upon the thought and trends of study in the field. One might say, in short, that the Award is for those who really start something. From this viewpoint, who can contest the rich deserts of HARRY MCQUAID?

Harry W. McQuaid

Blaine B. Wescott

Assistant to Executive Vice-President
Gulf Research & Development Co.
Pittsburgh

Citation "for application of alloy steels and irons in oil field and refinery equipment"

LIKE most investigators who have graduated to administrative duties, BLAINE WESCOTT is anxious to give a large share of the credit for the successful innovations which warranted his citation to his numerous associates during the 1930's. A postgraduate student and teacher at University of Pittsburgh (he received his bachelor's degree in chemistry from Syracuse, his hometown university), he became an "industrial fellow" at Mellon Institute and joined the oil production fellowship of Gulf Oil Corp. at its inception in 1927. Three years later this activity became a subsidiary of Gulf Oil Corp., with its own extensive laboratories and staff; its duties were extended to the coordination and execution of all the research activities of the parent corporation.

WESCOTT's early researches brought about the general recognition of the fact that corrosion fatigue was a major cause of failure of oil well drilling and production equipment — at least as far as the subsurface portion is concerned. This led to an extensive investigation of corrosion fatigue in the absence of air and to the general use of nickel and nickel-molybdenum steels (4600, 2300, 4800 series) for such applications by the entire oil industry. At the same time it was found that nickel steels had exceptionally low susceptibility to embrittlement by hydrogen sulphide, carried in certain types of petroleum, and which was the cause of many premature failures of equipment made of carbon steels. A study of corrosion of oil well equipment determined the causes of severe localized corrosion known as "ringworm corrosion" and resulted in the general adoption of full-length normalizing for sucker rods and tubing.

William Park Woodside

Chairman, Board of Directors
Park Chemical Co.
Detroit

Citation "for promoting the interchange of information about heat treatment and use of alloy steel during World War I"

JOURNEYMAN blacksmith and tool dresser with Cadillac Motor Co., steel salesman and pioneer serviceman for Crucible Steel Co. of America, founder of Steel Treating Research Society, manager of methods and standards for Studebaker Corp., vice-president of Climax Molybdenum Co., president and founder member of American Society for Metals, president of Park Chemical Co. — such are the various steps in the career of WILLIAM PARK WOODSIDE — "Bill" to a legion of friends in the metals and mechanical

world. Entering the automotive industry when the Cadillac four-cylinder car was taking the plunge and putting two alloy steels into the transmission gears and pinion, he lived through an epoch when these two have expanded into at least 40 different types of alloy steels, and have had much to do with the creation of a machine of great speed, comfort, quietness and safety.

To quote from his biography in *Metal Progress* for November 1938, "while selling toolsteel he called on many technical men in the automotive industry. It was a constant source of wonder to him that JIM JONES of ABC Co. had not the slightest idea what JACK SMITH, engineer for XYZ, a firm in the same field, was doing in the way of metallurgical progress, and the workmen of both companies seldom knew what either Jones or Smith were doing, or why. The result was almost complete ignorance and much pseudotechnical hocus-pocus. Regarding this fog with the penetrating eye of common sense, WOODSIDE decided that something should be done about it. To decide was to act. In October 1913 he invited 18 men to join in a 'metallurgical exchange', first called the Steel Treaters' Club."

This Detroit club grew into a local society; its value was so manifest that it organized similar groups in other cities — all doing yeoman service in making better and better ordnance and peacetime mechanisms. Shortly after World War I it amalgamated with a similar group centering in Chicago and the result is the American Society for Metals.

Wilbur Hering Armacost

Vice-President in Charge of Engineering
Combustion Engineering-Superheater, Inc.
New York City

Citation "for promoting the use of low-alloy steels for boilers and auxiliaries in high-temperature service"

FOR the first decade after his graduation from Armour Institute with a B.S. in mechanical engineering, WILBUR ARMACOST devoted his attention to refrigeration problems — and then went to the other extreme, joining The Superheater Co.'s staff in 1920. Many unsolved problems were appearing. When steam temperatures had reached 760° F. in the early 1930's, the limits for plain carbon steel had been reached, and it was necessary to develop special steels, even though there was but meager information concerning the influence of specific alloys. ARMACOST, therefore, worked with different tube manufacturers to produce low-alloy ferritic materials in tubular form satisfactory not only for high metal temperatures, but also for proper fabrication in the shop and easy handling in the field. These efforts extended over many years, since these low alloys offset the use of the very expensive austenitic materials later available. As time went on and steam temperatures went up, this cooperation between power engineers and steel metallurgists culminated in stabilized, low-alloy ferritic materials to operate up to 960° F. steam temperature.

It was also necessary to discover

Charles Morris Johnson

Chief Chemist, Park Works
Crucible Steel Co. of America
Pittsburgh

Citation "for early perfection of analytical methods for chemical control of alloys in steel"

GRADUATING in 1889 from the University and immediately becoming assistant chemist in the laboratory of Park, Brother & Co. at Pittsburgh (then the largest crucible steel plant in America), CHARLES MORRIS JOHNSON is now rounding out three score years of useful endeavor in a single locality. The permanent record of his work is contained in numerous patents and contributions to the technical press. The title of his second paper — "Rapid Determination of Nickel in the Presence of Chromium, Iron and Manganese" — set the stage for the achievements honored by the American Society for Metals' award.

Such articles as these made chemical and metallurgical history. The fundamental methods and their adaptations have become so commonplace that we are now apt to slight their development unless one can imagine the difficulties he would have today without these necessary refinements. In 1908 JOHNSON published the first edition of the "Chemical Analysis of Special Steels, Ferro-Alloys and Graphite". Work on it has been unceasing and, in its present fourth edition, it has become the steel analyst's bible.

CHARLES MORRIS JOHNSON has also an international reputation for devising useful alloy steels — particularly of noncorrosive and heat-resistant types — but at this place he is honored not for the building up of alloys but for tearing them apart. In this we add to laurels bestowed by others — Master of Philosophy by his Alma Mater, election to Sigma Xi, Fellow of the American Assoc. for the Advancement of Science "in recognition of his contributions to the chemistry of steel analysis, control, and manufacture".

how to join the low-alloy steels, not only in the shop but in the field, by simple, economical procedures. This — coupled with the use of the low-alloy material — has made it economical to go to higher steam temperatures and thus obtain higher thermal efficiencies.

Fred A. Loosley

Vice-President and Manager
Dominion Foundries & Steel, Ltd.
Hamilton, Ontario

Citation: "Inventor and producer of alloy steel of improved machinability, largely used in Canadian armored vehicles"

BORN in 1891, and educated in Hamilton and Toronto schools, FRED LOOSLEY was just getting started in a job at Dominion Foundries & Steel when he enlisted in the Canadian Army and served during World War I as a pilot in France. Upon demobilization he was appointed as supervisor of laboratories and inspection by his old employer, and in the intervening years has steadily risen in the organization.

Primarily interested in the metallurgical and technical control of production, he was faced with a new problem early in World War II, when his firm was asked to produce armor plate to British specifications and practices. Cast and heat treated armor was a real innovation in foundry practice, as all know. The analysis was nickel-chromium-vanadium, containing a total of 5.15% alloying elements. Mr. Loosley recalls that "in order to meet the ballistic requirements set up at that time, we found a Brinell hardness range of 353 to 395 proved most satisfactory. However, difficulties were encountered by tank manufacturers in machining this hard plate at joints and attachments. We therefore carried out a great deal of experimental work with different alloy steels and heat treatments to determine whether a more machinable plate could be produced and meet the ballistic requirements. In the meantime, the ballistic tests were made much more severe by changing from the use of sand filled shot to solid armor piercing shot. Plates were heat treated to varying degrees of hardness and tested ballistically in the new routine, and it was determined eventually that a chromium-nickel-molybdenum analysis containing as little as 3.62% total alloy was suitable when hardened to Brinell 255 to 285. This 'low' alloy plate gave excellent ballistic results and improved machinability."

Robert S. Archer

Vice-President
Climax Molybdenum Co.
New York City

Citation "for systematization of knowledge basic to the science of metals"

*BORN in Colorado, BOB ARCHER was fortunate enough, when undergraduate at Ann Arbor, to be assistant and reader to the late, great, EDWARD DEMILLE CAMPBELL, the blinded researcher in metals whose pioneering leadership the [illegible] delights to honor. One can hardly imagine a better training in the critical analysis of metallurgical data. It was almost immediately followed by association with another great metallurgist, ZAY JEFFRIES, at the Cleveland Laboratories of Aluminum Co. of America; in these years most of the forging and casting alloys of aluminum were formulated. Gradually what might be called a universal view of metallic alloys took form in the minds of JEFFRIES and ARCHER, correlating (for example) the diametrically opposite effects of tempering the aluminum and the iron alloys. Eventually was published "The Science of Metals", truly a milestone in the history of metals in America.

In this blasé age of 1949, the physico-metallurgist who is thinking in terms of atomic structure and electron spins may look down his nose at the viewpoint of these 1924 authors, who perforce adopted mechanical analogies in their "slip interference" theory of hardening and elsewhere throughout their writings, but these same critics would not remember the morass of pre-existing theories that were swept away by these same mechanical analogies. For a single example, a fresh start to the whole study of steel treatment was based on their view that "there are only three fundamental types of structure: *(a)* Solid solution of carbon in gamma iron (austenite); *(b)* atomic dispersion of carbon in alpha iron (freshly formed martensite); *(c)* dispersion of cementite in alpha iron. Further distinctions are of degree and not of kind."

Away with the beta iron (or irons) of Howe, Sauveur and the founding fathers!

*An extended biographical note was published in *Metal Progress* for November 1935, when Mr. Archer was President of the American Society for Metals. Since that date, he has received the Sauveur Achievement Award for 1945.

IMPROVING THE MACHINABILITY OF ALUMINUM BRONZE

By Vladimir A. Grodsky
Metallurgical Engineer
U. S. Naval Gun Factory
Washington

ALUMINUM BRONZE is a most useful alloy for castings and forgings, as is well known, and is used for many purposes in ship construction and naval ordnance. However the inherent hardness and toughness of the alloy cause a good deal of trouble in the machine shop — at least prevent speeds permissible for other metallic materials.

In the absence of an established machinability index for copper-base alloys, due primarily to the difficulty of quantitative comparisons in this respect, the following statement can be made: It is generally conceded that the machinability of aluminum bronze is not equal to most of the usual copper-base alloys, and is considerably inferior to the machinability of common phosphor bronze, even though the last edition of "Metals Handbook" (p. 885) gives both phosphor bronze and aluminum bronze a machinability rating of 20 (free-cutting brass is 100), and groups them with other copper alloys as "alloys difficult to machine".

It has been well known for some time that copper-base alloys containing lead can be machined with ease. It has been also found that presence of small amounts of lead has a beneficial effect upon the machinability of some steels. Steel with additions of lead as low as 0.07% show some improvement, which increases with further additions up to 0.5%. Commercially this was a pre-war innovation by Inland Steel Co. ("Ledloy").

Lead up to 0.25% cannot be detected microscopically if properly dispersed in the steel, chemical analysis being necessary for its determination. While a very small amount of lead will dissolve in molten iron, none of it will remain in solution in the solid phase. Since lead boils at 3160° F. and lead oxide at 2680° F., it is reasonable to assume that the absorption of the lead by the molten steel at 3000° F., more or less, occurs in the vapor phase of the lead. This explains its resulting extremely fine distribution. No segregation appears to occur when the lead additions are small.

The known improvement in machinability of wrought copper alloys by lead additions (noted, for example, by Harry P. Croft in an early article in *Metal Progress* — May 1931, p. 60), and the extremely low solubility of lead in copper (on the order of 0.002 to 0.005%), suggested the possibility of improving the machinability of cast aluminum bronzes by such a treatment. Of course this necessitated an investigation of the effect of lead on the mechanical properties of this important engineering alloy.

Four melts of 10% aluminum bronze were prepared meeting Federal specification QQ-B-671a, Class D, to which 3%, 2%, 1% and 1% lead were added respectively. Otherwise the melts complied

NOTE: The opinions in this article are those of the author and do not necessarily reflect the official views of the U. S. Navy.

Appreciation is due to J. E. Crown, master mechanic of the foundries, and J. A. Kingsbury, materials engineer, for helpful suggestions; to P. O. Ady, quarterman, for melting, and J. Maltz, metallurgist, for heat treating the samples described herein.

with the composition requirements (>78% Cu, 7 to 12% Al, 2.5 to 4.5% Fe, <3.5% Mn, <5.0% Ni, <0.5% Sn, <0.50% all others). Degassing was done by small amounts of lead chloride.

The metallic lead was introduced just before pouring the metal, being vigorously mixed in with a skimmer. This mixing was done carefully to avoid stirring air into the melt. The pouring temperature was approximately 2150° F.

Mechanical properties of this special aluminum bronze, cast in sand with no further heat treatment, are as shown in Table I.

Table I — Properties of Leaded Aluminum Bronze, Sand Cast

	Heat A (3% Lead)	Heat B (2% Lead)
Yield point	43,000 psi.	36,000 psi.
Tensile strength	78,500	82,500
Elongation	6.2%	13.4%
Rockwell hardness	C-8.5	C-4.0*

*Hardness, chill cast: C-16.0.

Investigation proved alloys A and B could be welded electrically, using commercial aluminum bronze welding wire; although the literature states that lead prevents the hot rolling of aluminum bronzes, these heats were forged without cracking. They were easily machinable; deep cuts could be taken without dulling the cutting tool. Chips were small and were of a distinctly grayish color.

Heat B was further subjected to heat treatment, which consisted of heating the alloy to 1450° F., quenching in brine, heating again to 1000° F. and quenching in brine for the second time. (A second quench was considered better than a slow cool.) The properties obtained in Heat B after this heat treatment may be compared with properties specified for Grade D, heat treated.

	Heat B (2% Lead)	Grade D
Yield point	49,500 psi.	>45,000 psi.
Tensile strength	90,000	>90,000
Elongation	5.0%	>6%
Hardness	C-21.5	C-5 to C-21

The fracture of the bars was grayish, the machining very easy, the chips breaking into small fragments.

The other two melts made to specification were treated with 1% lead, sand cast in standard test bar molds, heat treated and tested. Properties in various stages for these Heats C and D are given in Table II.

All the test bars of Heats C and D machined very well. Deep cuts were made without affecting the cutting edge of the tool. The chips broke up easily and were light gray in color.

A test piece from Heat A containing 3% lead was subjected to a 1000-hr. corrosion test in a spray of 20% sodium chloride dissolved in water. Less than 10% of the surface of the test piece was covered with corrosion products; the remainder of the surface was not affected.

Summary

The as-cast mechanical properties of the 10% aluminum bronze with 3% lead were, as could be expected, somewhat lower than the as-cast properties of the bronze with 2% lead. Still, the bronze with 3% lead could be readily forged and electrically welded.

The aluminum bronze with 1% lead had very good machinability and also responded to heat treatment in a greater degree than bronzes with 3% and 2% lead added to them.

The mechanical properties of a heat treated aluminum bronze with 1% lead differed little from the usual properties of the same bronze containing no lead.

Therefore, it can be assumed that 0.5 to 1% lead may be safely added to an aluminum bronze, greatly improving its machinability and not reducing, to any appreciable extent, its mechanical, heat treating, forging and welding properties.

Table II — Properties of Heat Treated Aluminum Bronze
(Hardness as cast, C-4.0)

	Heat C With 1% Lead			
First quench	1500° F.	1500° F.	1500° F.	1500° F.
Second quench	900	1200	1200	1250
Yield point	54,500 psi.	51,750 psi.	55,250 psi.	44,000 psi.
Tensile strength	95,750	94,500	98,000	87,000
Elongation	1.6%	9.0%	8.0%	13.0%
Reduction of area	3.3	13.2	12.0	16.7
Hardness	C-27.0	C-24.0	C-24.0	C-13.0
	Heat D With 1% Lead			
First quench	1450° F.	1600° F.	1600° F.	1600° F.
Second quench	1000	1200	1250	1300
Yield point	53,500 psi.	66,250 psi.	57,500 psi.	55,000 psi.
Tensile strength	96,750	108,250	104,500	103,000
Elongation	6.5%	7.0%	8.0%	8.2%
Reduction of area	9.0	11.0	13.4	13.4
Hardness	C-23.0	C-26.5	C-22.0	C-20.0

CORRESPONDENCE

Recent Metallurgical Progress in France

PARIS, FRANCE

To the Readers of METAL PROGRESS:

In the December issue of *Metal Progress*, under the title "Recent Metallurgical Progress in France", appear several comprehensive and sympathetic abstracts of papers from *Revue de Métallurgie* for 1944.

Is is therefore with painful surprise that I read the preface to this group of reviews, which shows how very differently the abstracter has imagined the conditions under which we actually lived and toiled, our aims as well, from what was the actual situation.

Frenchmen were not "encouraged [by the Germans] to do substantial scientific work", to quote the abstracter. As for my own writings — which were adequately summarized in that same series — they were done under conditions bordering on starvation for myself and my family.

If the work done by the French metallurgists appeared "at least as good and thorough as before the war", this is only a testimony to what can be achieved under the most trying circumstances by people whose only aim was to serve faithfully their country and their cause in the hours of need and trial.

May I also add, that the articles referred to were published not under the German occupation, but after the liberation, the January issue of *Revue de Métallurgie* coming from the press in October 1944. Thus, not only was our work meant to diffuse knowledge about American practices among the younger generation of French metallurgists, and so strengthen the ties between our coming generations and our faraway friends, but it was so timed as in no way to benefit our common enemy.

N. T. BELAIEW

[The Editor regrets sincerely the publication of any matter which reflects on the French metallurgical fraternity; his critical faculties were indeed asleep when this material passed over his desk. His sympathy with the French nation is sufficiently established from *Metal Progress*' campaign in 1945, joined by 600 Americans, for sending food boxes to French metallurgists, scientists and teachers.

Ex parte judgment of the motives of any man in period of stress is most hazardous. It is impossible so to judge any group of men.]

Possible Embrittlement of Cold Worked 18-8 at Moderate Temperatures

MILWAUKEE, WISCONSIN

To the Readers of METAL PROGRESS:

We have recently learned of some tests which indicated that the common grades of 18-8 stainless steel, when cold worked, were somewhat brittle at moderate temperatures — say 350° F. — as judged by the figures for elongation in the short-time, high-temperature tensile test. This temperature is much too low for any of the ordinary ailments, such as sensitization, sigma phase, or 475° brittleness — in fact, it is in the low range for stress relief, and all the published figures readily available show that such mild heating does not change tensile test results, at least when tests are made at room temperature.

A preliminary investigation at A. O. Smith Corp.'s metallurgical research department showed some interesting trends, perhaps unobserved previously. Bars of Type 302 (18-9, 0.14% C), Type 304 (19-9, 0.07% C), Type 347 (18-11 Cb, 0.07% C) and Type 317 (19-13, 3% Mo, 0.06% C) were water quenched from 1950° F. and tested as 0.357-in. diameter rounds at 70, 350 and 500° F. Comparing tests at 350 and 500° F. with those at room temperature the tensile strengths were reduced by 21,000 psi. and elongation in 1.4 in.

by 10% (55% at room temperature versus 45% at 350 and 500° F.). However, the reduction of area remained the same.

While this loss in ductility may not be considered slight; nevertheless, the elongation values remain high enough to warrant little further concern.

A different story applies to Type 304, half-hard flat tensile specimens. Results follow:

Test temperature	70° F.	350° F.	500° F.
Tensile strength, psi.	150,200	135,500	132,200
Elongation, % in 2 in.	17.0	8.5	5.5
Bend test, angle of bend	100°	70°	—
Elongation over ½ in.	32%	22%	—
Elongation over 1 in.	16%	11%	—

It will be observed that this cold worked 304 lost about half its ductility (as measured by elongation in 2 in.). Whether an elongation figure less than 10% at a working temperature of 350° F. may or may not be a serious consequence will depend on the application of the material. The fact that the tensile strength on annealed and half-hard stainless decreases 15,000 psi. at 350° F. may be of greater concern.

Any further information along this line, derived from tests or plant service, would be greatly appreciated.

M. A. Scheil
Metallurgical Research Laboratory
A. O. Smith Corp.

Valuable Scrap

Richmond, Va.

To the Readers of Metal Progress:

Rumors have reached my ears that scrap metal (which I understand is a required raw material for some steelmaking processes) sold for a higher price than the ingots into which it is poured. This is doubtless an exaggerated way of saying that scrap metal is valuable — a truism that has been in the minds of the Department of Highways of the Commonwealth of Virginia when considering the disposal of serviceable old bridges that must be replaced, either to widen the roadway or to carry heavier loads.

The accompanying photograph shows the E Pluribus Unum bridge over the New River at Lowman's Ferry.

It is made of a number of old bridges; each of the old spans was match-marked, taken apart piece by piece, transported to the new site and re-erected in the usual manner. Note that the central span was once a swing bridge; it came from Norfolk.

There was no extensive replacement of metal due to deterioration, but of course all the metal was thoroughly cleaned and painted during and after erection. It was a most interesting project, and the economics (at least) bordered on the spectacular, but unfortunately for an engineering story, the details of handling were severely prosaic.

W. R. Glidden
Bridge Engineer
Virginia Department of Highways

Fundamentals of Creep

East Pittsburgh

To the Editor of Metal Progress:

When reviewing recently published items concerning so-called creep tests, I saw the item in "Critical Points" for February 1948 entitled "Fundamentals of Creep", and I think it brings up some matters worthy of comment.

The Editor asks for tests on spectroscopically pure metals to "divulge fundamental principles",

An Ideal Way to Use Scrap Is Illustrated by the Bridge Over the New River in Pulaski County, Va. This bridge, 1400 ft. long, is made from several old ones (three single spans, one swing bridge, one three-span bridge)

mentioning specifically lead, silver, gold, aluminum and zinc, at least three of which metals will recrystallize at room temperature and the others at temperatures slightly above atmospheric and at which creep tests might probably be made. I can imagine nothing more difficult to interpret than the results of creep while recrystallization is in progress. Furthermore, spectroscopic purity does not imply the absence of the highly noxious nonmetallic elements, nitrogen and oxygen, which have major effects on creep and other mechanical properties.

I am therefore unable to accept the conclusion, based on the exhaustive tests on lead which are mentioned by the Editor, that there is no correlation between creep and tensile strength.

And now a word in defense of our complex practical alloys. The ones we deal with here, at least, despite eight or nine metallic components, are really simple solid solutions hardened by a single precipitating agent, and these alloys behave in a regular and predictable manner. Nitrogen, oxygen and carbon are present in very small contents and are combined in innocuous compounds. Furthermore, the test temperatures commonly used are well below temperatures causing recrystallization and grain growth, and the alloys are completely recrystallized before testing.

Even for our simple alloys we have not been able to develop, as yet, any broad fundamental principles, although I am convinced that this will be done as time goes on and the effects of major composition and treatment variables are clearly established. I am also optimistic about the development of correlation between creep and tensile properties, particularly in view of the fact that the so-called simple tensile test is not yet fully understood nor the results thereof even adequately recorded. Standard practice neglects to record both load and extension at the ultimate and at the breaking load. Until we thoroughly understand the tensile test, how can we ever expect to develop correlations between it and creep tests?

HOWARD SCOTT
Manager, Metallurgical & Ceramic Dept.
Westinghouse Electric Corp.

Increased Wear Resistance by Induction Hardening

BETHLEHEM, PA.

To the Readers of METAL PROGRESS:

In connection with the Editor's account of "Large Cylinder Liners, Induction Hardened" at the National Supply Co., published in the January issue of *Metal Progress*, I was interested to note that cylinder liners made of 0.50% Cr, 0.55% C steel (and surface hardened using induction heating) appear to stand up in service as well as high-carbon carburized liners. The Editor considered this performance surprising, since it is commonly stated that excess carbides in the microstructure are necessary to resist scouring wear, and he considered that such excess carbides would not be present in a hardened steel containing 0.50% chromium, 0.55% carbon.

Experimental work, currently under way at Lehigh University, indicates that satisfactory performance of the induction hardened liners might be expected because of the *presence* of undissolved alloy carbides (in this case chromium) existing in the hardened structure.

The common classification of alloying elements into two groups, carbide formers and ferrite strengtheners, assumes significant importance in induction hardening, where the heating rate is extremely rapid and time at temperature is normally zero. Our preliminary data show that under these conditions of heating, alloying elements classed as carbide formers are only partially dissolved in the austenite and will therefore exist as undissolved carbides in the structure resulting from austenite decomposition. Such a response from carbide-forming elements is apparent during induction heating of conventional engineering alloy steels, such as A.I.S.I. 4150 or 4340. Our studies indicate the nonhomogeneous austenite formed during such short heating cycles may actually change the conventional TTT (time, temperature, transformation) curve of A.I.S.I. 4340 steel, so that it looks nearly like the conventional curve for A.I.S.I. 2340.

The degree of carbide solution will naturally increase as the length of the heating cycle is increased. Since, however, the heating cycle used for the large cylinder liners described is very short (feed of coil over work equals ½ in. per sec.) it seems reasonable to assume that the chromium present in the liners does not dissolve in the austenite during heating, but remains as small, rather well distributed alloy carbides in a martensitic matrix after quenching. This structure should provide good wear resistance for the liners.

We are now considering some wear tests to develop the thought that induction hardening, which normally results in the structure described above when carbide-forming elements are present, actually may provide an important increase in the wear resistance of engineering alloy steels when the temperatures developed during use are not very high.

JOSEPH F. LIBSCH
Consulting Metallurgist
Lepel High Frequency Laboratories, Inc.

JANE RUSSELL Starring In R K O's "IT'S ONLY MONEY"

This is more than just a Pretty Picture

OF COURSE . . . Jane Russell on her new Indian motorcycle is mighty attractive, *But* . . .

If you're a motorcycle enthusiast, you'll look further and see more. You'll find that the new Indian models are different—less than half the weight of former motorcycles—yet they deliver more horsepower per pound than any stock machine previously marketed.

Why? Some of the answers are illustrated at the right. To attain maximum *durability* and to build a *high-powered, light weight* and *safe* machine, engineers of the Indian Motocycle Company, Springfield 4, Mass., specified nickel alloy steels and irons for vital parts, including those pictured.

Centrifugally cast cylinder liners of nickel iron.
Transmission gears of 3115 type Ni-Cr steel
Indian crankshaft of 3140 Ni.Cr steel
3140 Ni-Cr steel connecting rods
EMBLEM OF INCO SERVICE

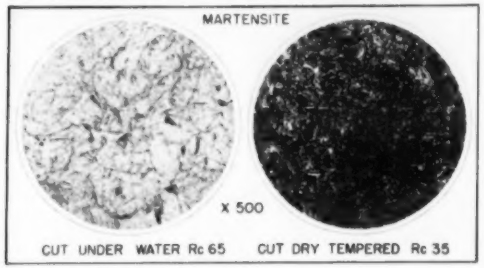
THE INTERNATIONAL NICKEL COMPANY, INC.

67 WALL STREET
NEW YORK 5, N.Y.

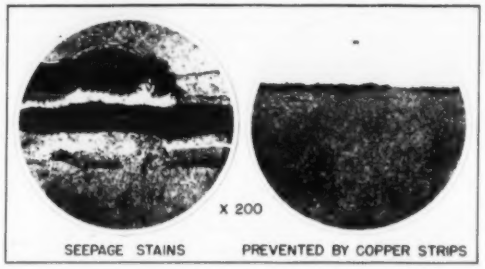
Metallographic Technique for Steel: Polishing

*Sheet 1 of Six Prepared by Research Laboratory, U. S. Steel Corp.**

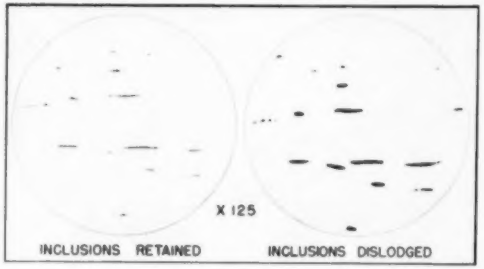
UNDER WATER AND DRY CUTTING



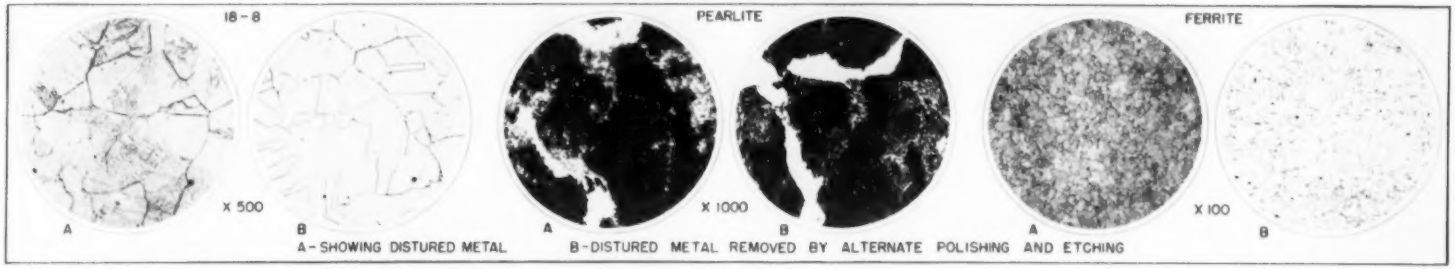
PREVENTION OF SEEPAGE IN CLAMP MOUNTS



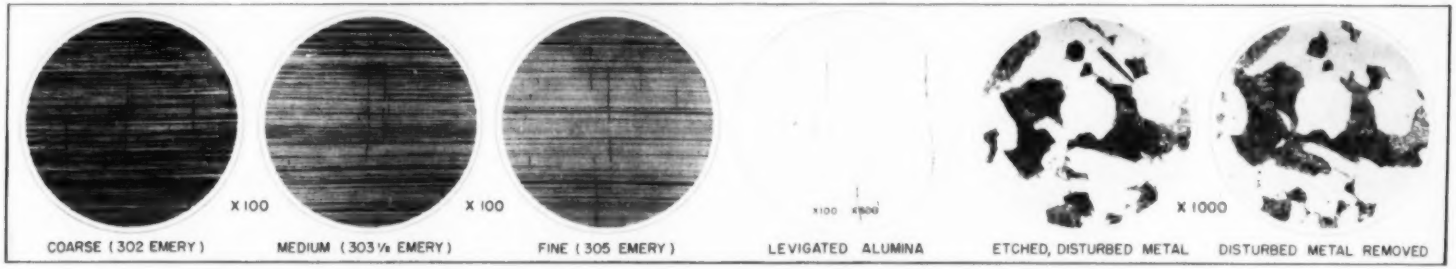
PRESERVATION OF INCLUSIONS



DISTURBED METAL AND ITS ELIMINATION



STEPS IN POLISHING — LEAD LAP METHOD



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See also "Metallographic Technique for Steel", by J. R. Vilella, published by The American Society for Metals

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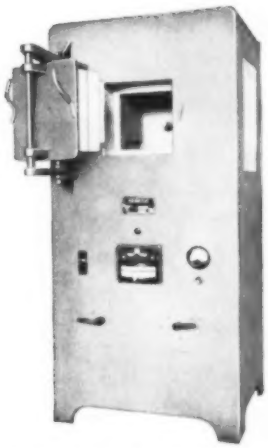

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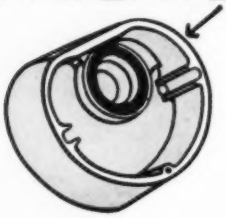

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PROPERTIES OF TITANIUM AND TITANIUM ALLOYS

Last month *Metal Progress* published eleven brief articles on the production and fabrication of titanium, and the titanium programs of four Government agencies. The series is concluded here with nine articles concerning properties, and a selected bibliography. Most of the articles are condensed versions of papers presented at a recent Symposium on Titanium, sponsored by the Office of Naval Research.

Titanium melts at a high temperature (3150° F.) and, when molten, reacts with virtually everything it touches. Some gases and metallic elements have important effects when present in the solid metal; for instance, small amounts of oxygen and nitrogen decrease the ductility markedly. Furthermore, specimens prepared by sintering and those made by melting may differ considerably in their properties. But after all due allowances are made for present uncertainties, titanium is still a light, strong, ductile, corrosion resistant metal whose structural applications will depend largely on getting the cost of the metal down from its present high level of $5 a pound. Just how soon titanium will come into widespread industrial use will depend also on the development of titanium alloys for specific purposes. Considerable progress in alloying is reported in the last five articles of the present series; serviceable titanium alloys are in prospect, both for use at normal and at elevated temperatures.

The papers presented at the O.N.R. symposium are being published in full by the Government Printing Office, and the complete report can be obtained from the Superintendent of Documents, Washington 25, D. C.

TITANIUM

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COMPOSITION, STRUCTURE & PROPERTIES OF IODIDE TITANIUM

By Felix B. Litton
Foote Mineral Co.
Philadelphia

By Bruce W. Gonser
Battelle Memorial Institute
Columbus, Ohio

IN THE IODIDE PROCESS, described by Bruce Gonser in last month's *Metal Progress* (p. 193), crude titanium is separated from embrittling elements such as oxygen, nitrogen, hydrogen and carbon. As operated by Foote Mineral Co., the iodide process deposits titanium at an average rate of about 250 g. per bulb per 16-hr. day. The resulting rods are compact and can be drastically cold fabricated (for instance, cold rolled 95%) without being melted or pressed and sintered.

The physical properties of iodide titanium depend primarily on the impurities in the raw material and on the ease with which those impurities are transferred to the growing rod. The common elements that are either codeposited with titanium or have a harmful effect on metal transfer are silicon, aluminum, iron, magnesium, calcium and hydrogen. Oxygen, nitrogen and carbon apparently are not transferred.

A typical spectrographic analysis of Foote's iodide titanium produced in a metal bulb is: 0.01 to 0.05 silicon, 0.01 to 0.05 iron, 0.001 nickel, 0.005 magnesium, 0.005 to 0.01 manganese, 0.05 to 0.1 aluminum, 0.01 to 0.05 calcium, 0.001 to 0.005 copper, 0.05 to 0.1 molybdenum, and a trace of zinc. Tin and zirconium were not detected.

The average tensile properties of iodide titanium sheet are:

	Annealed★	Rolled†
Tensile Str.	32,000 psi.	107,000 psi.
0.2% Yield	17,500 psi.	90,000 psi.
Elongation (2 in.)	55%	2.5%
Reduction of Area	60%	30%
Modulus, 10^6 psi.	11.2	16.2

★Vacuum, ½ hr. at 1380° F.
†Cold rolled about 95% from rod.

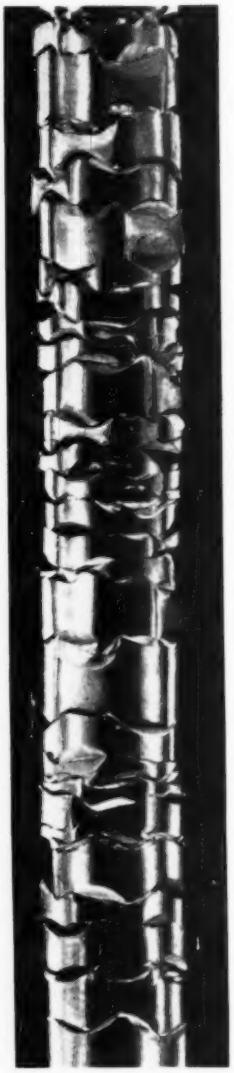


Fig. 1 — Surface Structure of Iodide Titanium, ⅝-In. Diameter

AS DEPOSITED, iodide titanium is coarsely crystalline. The type of deposit depends on the temperature of the operation: Deposits from a run with the charge at 1020° F. are finer grained but rough; those from low-temperature runs are larger grained but each grain is smoother (Fig. 1). Both types are bright and attractive in appearance unless cooled so slowly that residual iodine in the tube condenses on the deposit.

Purity — Analyses for minute amounts of impurities in titanium have not been standardized. Chemical analyses show the carefully prepared soft metal to contain from 0.02 to 0.03% carbon and 0.002 to 0.003% nitrogen, with occasional products running up to 0.009% nitrogen. No oxygen analyses are available, but the oxygen content is believed to be lower than the nitrogen. Spectrographic analyses show less than: 0.04 silicon, 0.04 iron, 0.05 aluminum and 0.002 sulphur.

For an operating guide, the hardness of the metal as deposited is commonly taken as an indication of purity. Vickers hardness values range from 60 to 115. The normal metal from high-temperature runs in a glass unit usually averages between 70 and 80; that from a "cold" bulb has been from 80 to 100; and from a metal bulb, 75 to 85.

Metallographic Structure — Microstructures of iodide and magnesium-reduced titanium are shown in Fig. 2. Water quenched titanium that contains nitrogen has a martensitic structure [similar to Fig. 1 on p. 364] but quenched iodide titanium does not (see lower left micrograph in Fig. 2).

Physical Properties — The density of iodide titanium (4.5 g. per cu.cm.) is not much different from that of magnesium-reduced titanium. Likewise, the lattice constants ($a = 2.946$, $c = 4.686$, from our unpublished data) are nearly the same as those reported by Greiner and Ellis (*Metals Technology*, September 1948) for magnesium-reduced titanium obtained from the Bureau of Mines. Coefficients of thermal expansion (4.55 per °F. from 68 to 572° F.) are similar also.

The melting point is 3135 ± 20° F. Allotropic transformation temperatures for ductile titanium have been obtained in the range from 1616 to 1632° F. The low-temperature form is close-packed hexagonal, the high-temperature form body-centered cubic. With both iodide and magnesium-reduced titanium, quenching from the beta field does not affect the hardness much.

Table I — Tensile Properties of Titanium

Property	Iodide Titanium	Magnesium-Reduced*
Melted, Hot Worked and Vacuum Annealed		
Tensile Strength	38-48,000 psi.	80,000 psi.
Yield (0.2% offset)	20-24,000 psi.	72,000 psi.
Proportional Limit	10,000 psi.	38,000 psi.
Elongation	40% in 1 in.	25% in 2 in.
Reduction of Area	75%	55%
Modulus, 10^6 psi.	14-15.5	16-16.5
Cold Worked, 50% Reduction		
Tensile Strength	97,000 psi.	125,000 psi.
Yield (0.2% offset)	87,000 psi.	110,000 psi.
Elongation	11% in 1 in.	12% in 2 in.
Reduction of Area	75%	30%

*Most of these data are from E. I. du Pont Co.

The most marked difference between iodide and magnesium-reduced titanium is in electrical resistivity. The resistivity of iodide titanium, 42 microhm-cm., compares with 55 microhm-cm. obtained by Greiner and Ellis; the temperature coefficients are 0.0055 and 0.0033 per °C., respectively.

Mechanical Properties — Table I gives some tensile properties of iodide and magnesium-reduced titanium. The *rate* of work hardening is about the same for both (an average of 900 psi. increase in tensile strength for each 1% reduction), but iodide titanium can be reduced more than 95% by cold rolling before the edges of the sheet begin to crack, whereas 60% is the maximum for magnesium-reduced titanium. With these maximum amounts of cold reduction, the tensile strength will reach about 130,000 psi. for each type of titanium.

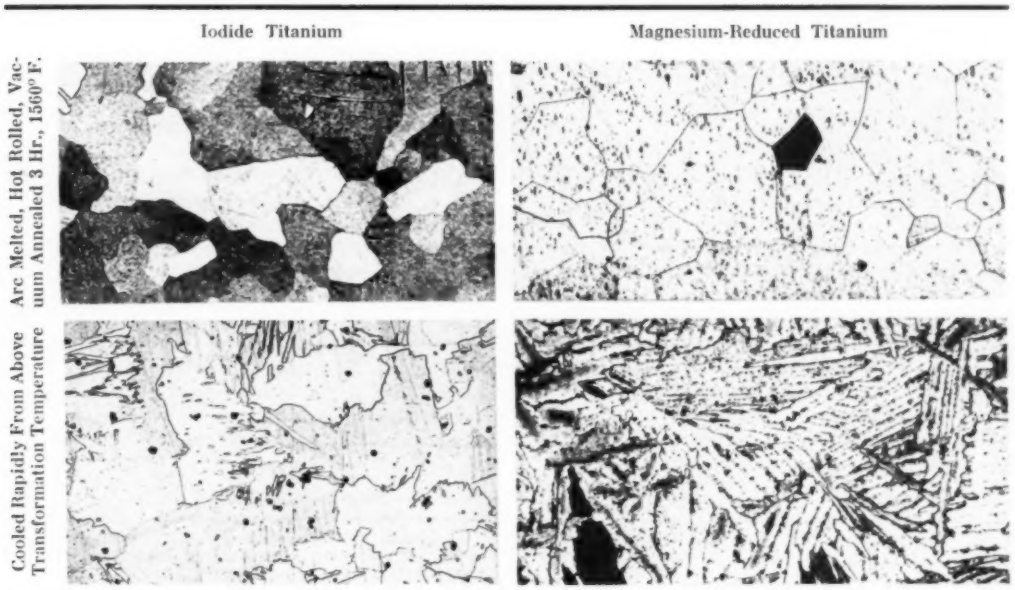

Iodide Titanium
Magnesium-Reduced Titanium
Arc Melted, Hot Rolled, Vacuum Annealed 3 Hr., 1560° F.
Cooled Rapidly From Above Transformation Temperature

Fig. 2 — Iodide Titanium and Commercial Magnesium-Reduced Titanium, After Annealing and After Rapid Cooling From Above Transformation Temperature. Etchant: 2% HF, 3% HNO_3 in water. 100 ×

PROPERTIES OF WROUGHT COMMERCIALLY PURE TITANIUM PREPARED BY ARC MELTING & CASTING

By C. I. Bradford, J. P. Catlin and E. L. Wemple
Remington Arms Co., Inc.
Bridgeport, Conn.

IN 1947 the Remington Arms Co. embarked on a broad program to diversify and expand the company's business outside of arms and ammunition. One study which received early attention in this program was the possibility of fabricating ductile titanium metal. The current over-all objective of the Remington program is to produce titanium and titanium alloys in simple fabricated forms (such as rod, sheet and wire) at a price that will permit the metal to be made available on a tonnage basis for structural and engineering uses. Remington's program has progressed to the point where ingots weighing from 20 to 25 lb. are being cast and small quantities of narrow sheet and round rod are being produced. Our main effort at present is to develop titanium alloys. Although this work has not advanced far enough so that it can be discussed here, the preliminary results make us enthusiastic regarding the development of outstanding titanium alloys.

Remington commercially pure titanium contains about 0.3% carbon and from a few hundredths to a few tenths per cent each of oxygen, nitrogen and iron, with traces of other elements.

Titanium is light, strong, ductile and corrosion resistant. Comparative data for titanium, 75S-T aluminum and 18-8 stainless steel are shown in Fig. 1 and Table I.

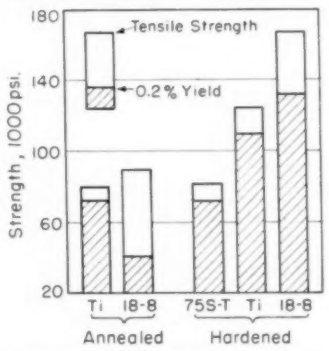


Fig. 1 — Comparison of the Strength of Titanium, 75S-T Aluminum and 18-8 Stainless

The high melting point of titanium should be a considerable advantage when the metal and its alloys are used in high-temperature mechanical devices. The low thermal expansion also will be advantageous in applications where the metal is exposed to high temperature, because thermal stresses are reduced to a minimum and close tolerances are feasible for devices that operate over a considerable range of temperature.

Mechanical Properties — Many of the data presented here were obtained by members of the staff of Battelle Memorial Institute, on rod and sheet titanium produced by Remington. Because all of Remington's titanium has been melted and cast, some of the data do not agree with those published by others on sintered titanium.

Figure 2 shows the effect of cold work on the tensile properties of Remington commercially pure titanium. The relatively high tensile and yield strengths of the annealed material are found in combination with good elongation, and the strength increases considerably with only moderate amounts of cold work. For example, 20% cold work raises the yield strength to about 100,000 psi., which is only slightly less than the yield strength obtained through 50% cold work. Thus, moderate cold working by commercial forming processes will increase the strength of tita-

Table I — Some Physical Properties of Commercially Pure Titanium, 75S-T and 18-8

Metal	Density, G. per Cu.Cm.	Young's Modulus, 10^6 Psi.	Melting Point (Solidus)	Thermal Expansion per °F.	Electrical Conductivity, % I.A.C.S.	Thermal Conductivity, Btu./Ft.²/In./°F./Hr.
Titanium	4.5	15.5	3140° F.	5.0×10^{-6}	3.2	105
75S-T Aluminum	2.8	10.3	890	12.7	30	835
18-8 Stainless Steel	7.9	28	2550	9.5	2.5	115

nium. Small amounts of cold work reduce the ductility considerably, but at 50% cold work, titanium still shows 12% elongation.

Some tensile properties of forged titanium bar over a considerable range of temperature are shown in Fig. 3. These data represent the results of short-time tests in which the specimen was held at temperature about 30 min. before being tested.* The curves indicate that *(a)* titanium has usable strength up to 800° F., being about twice as strong at 800° F. as the strongest aluminum alloy at 400° F., *(b)* the modulus of elasticity of titanium remains virtually constant between room temperature and 800° F., an important matter in applications that involve elastic stability at high temperature, and *(c)* the strength and modulus are high at subzero temperatures. Although it is not shown in Fig. 3, ductility is also satisfactory at subzero temperatures; the elongation of forged titanium bar is nearly constant between −75 and 800° F.; actual values are from 15 to 20% in 2 in.

Compression data on sheet and forged bar show about the same values as in tension, but the modulus is slightly higher in compression.

Torsion tests on forged titanium bar indicate a modulus of elasticity in shear of 6,600,000 psi. and a torsional shear strength of 101,300 psi.

Titanium rivets ⅛ in. in diameter have a shear strength of 82,000 psi., compared with 47,000 and 41,000 psi. for 75S-T and 24S-T, respectively.

Bearing strength tests on titanium sheet show:

	0.5% Yield	Ultimate
Annealed Sheet	117,000 psi.	177,000 psi.
25% Cold Worked	170,000	216,000

*In other laboratories, tensile strength at 600° F. after holding specimens 1000 hr. at 600° F. was about the same as our results after 30 min. at 600° F.

At room temperature and above, titanium has a higher Charpy value than 75S-T or 24S-T. At −75° F., the Charpy value for titanium is about the same as for 24S-T (from 10 to 12 ft-lb.).

Fatigue data on titanium are rather meager. However, a fatigue limit of 55,000 psi. was obtained on sheet having a tensile strength of 130,000 psi. This test was run in a Krouse direct repeated-stress machine. [For reports of higher fatigue limits, see p. 355.]

Creep of titanium was negligible under a stress of 25,000 psi. at 600° F. At 800° F. and 16,000 psi., the average rate of creep was 0.000015% per hr., over a period of 1125 hr.

Miscellaneous Fabricating Properties — Commercially pure titanium can be forged readily between 1600 and 1800° F. The machinability is similar to that of austenitic stainless steels; we generally recommend using the same tool angles, cutting speeds and feeds as are required for 18-8. As forged, titanium may have a hard surface scale requiring carbide tools to remove. Chips from the drilling of titanium are tough and stringy and it is frequently necessary to clear the drill by removing it from the work.

The General Electric Co. River Works at West Lynn, Mass., and several other companies have been conducting preliminary welding experiments with Remington titanium. These experiments indicate that titanium can be spot welded, seam welded and inert-arc welded to other pieces of titanium. Other types of welding have not been developed for titanium and we have no experience in welding titanium to other common structural materials. Information on the spot welding of titanium was published in *Metal Progress* last month, p. 200. [See also p. 355 in this issue.]

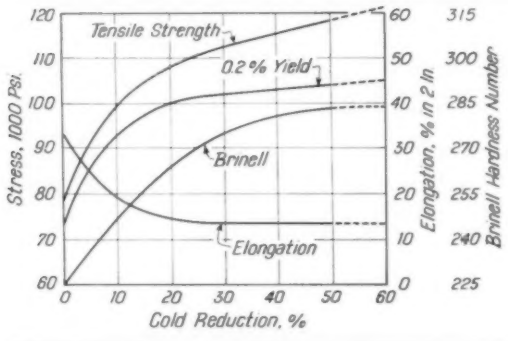


Fig. 2 — Work Hardening Characteristics of Commercial Titanium Produced by Casting

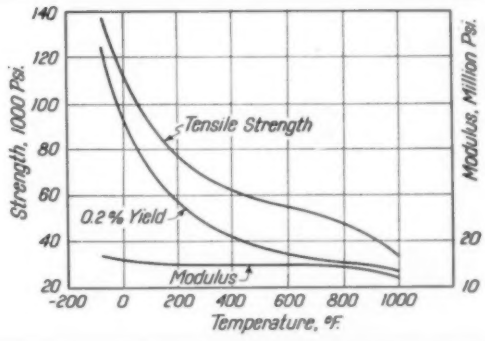


Fig. 3 — Effect of Testing Temperature on Tensile Properties of Forged Titanium Bar

Annealed titanium will take a 3*T* minimum bend radius and quarter-hard titanium a 5*T* minimum bend radius. Much development work remains to be done for drawing, cupping, spinning, die forming, extruding, and other forming processes.

Corrosion — Samples of Remington titanium have been exposed to air at temperatures from 600 to 1500° F. for 1000-hr. periods. Measurements of weight and strength after these exposures indicate that titanium is suitable for long exposure to air up to 1300° F. Above this temperature, the metal is embrittled.

Samples of Remington titanium have been exposed to the following tests at Kure Beach, N. C., for periods up to four months: jet aspirator, basin immersion, flowing sea water immersion, and exposure to the atmosphere 100 and 1000 yards from the ocean. Titanium was completely resistant to attack under all these conditions of exposure, indicating that titanium is in the same class as platinum and Hastelloy C in its resistance to marine corrosion. Figure 4 shows various metals after immersion in sea water for four months.

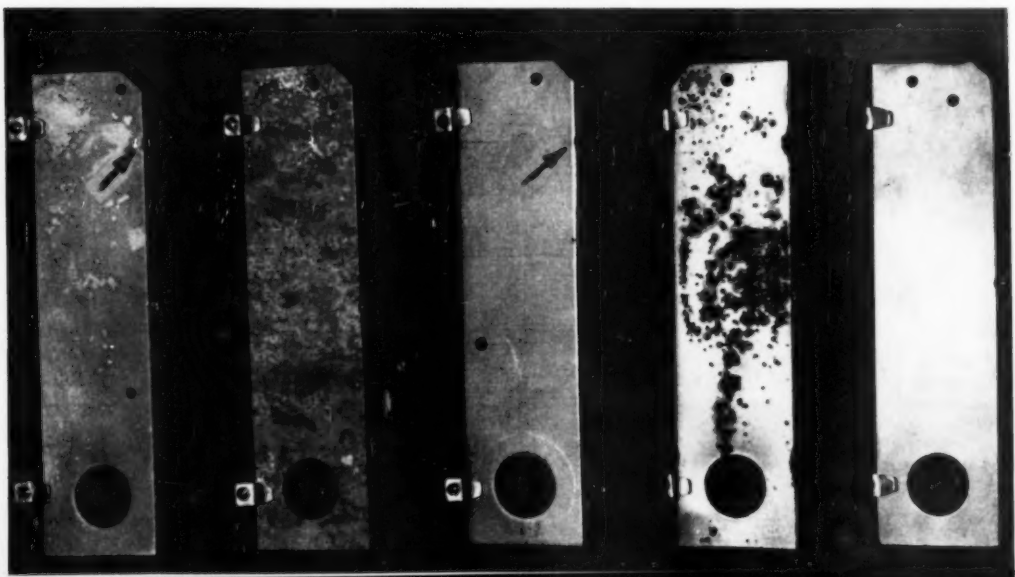
Laboratory tests indicate that titanium is resistant to the following aqueous solutions: nitric acid at 77° F. in all concentrations up to 95%, 65% nitric acid from 130° F. to the boiling point, dilute warm hydrochloric acid, dilute warm sulphuric acid, aqua regia at 86° F., water saturated with chlorine at 176° F., chlorine saturated with water at 176° F., bleaching solution at 86° F., boiling 10% solution of ferric chloride, boiling 28% solution of calcium chloride, and boiling 10% solution of sodium hydroxide.

Possible Applications — Titanium fills a gap between aluminum alloys and stainless steel insofar as modulus, density, and strength at intermediate temperatures are concerned. Titanium resists corrosion in sea water and marine atmospheres better than austenitic stainless steel, Monel, and the cupro-nickel alloys, and as well as the best known materials (platinum and Hastelloy C). The strength-weight ratio, as compared with aluminum alloys and stainless steel, may or may not be favorable, depending on the specific application. Where titanium can be substituted section-for-section in place of stainless steel, a 40% saving in weight will result.

Commercially pure titanium might find application in the following services: airframe skins and structures where intermediate temperatures or corrosion problems are encountered, aircraft power plants where temperatures between 300 and 800° F. are involved, naval or marine applications in which the combination of superior corrosion resistance and light weight are important, industrial equipment in which resistance to corrosion by specific agents can be utilized, miscellaneous applications in which a combination of light weight, corrosion resistance, and high strength at normal and moderately elevated temperatures are required.

Commercially pure titanium is primarily a new base metal whose alloys have not yet been developed. When information on the structure, properties and fabrication of titanium alloys is available, the usefulness of the new metal can be evaluated much more accurately.

Fig. 4 — Specimens Immersed Continuously for Four Months in Sea Water at Kure Beach, N. C.



FATIGUE & CORROSION OF SINTERED & ROLLED TITANIUM*

By W. Lee Williams
and William C. Stewart
Metallurgical Laboratory
U. S. Naval Engineering Experiment Station
Annapolis, Md.

OUR OBJECTIVE is to find where titanium can serve the Navy better than any other material. The data reported here were obtained on titanium made by the Bureau of Mines in the following forms: sheet 0.0625 in. thick and $6\frac{1}{16}$ in. wide, bar $\frac{7}{8}$-in. diameter, and wire 0.1265-in. diameter. The sheet was hot rolled and then finished with 40% cold work. The bar stock was hot rolled and finished with 35% cold work as a square bar, then machined. The wire had been swaged and finished with 40% cold work.

The average properties listed below were determined with standard 0.505-in. specimens for the bar stock and with full-thickness sheet specimens 0.75 in. wide.

	Bar	Sheet
Tensile strength	97,800 psi.	123,000 psi.
0.1% Yield strength	78,800	86,800
Elongation in 2 in.	8.5%	10.0%
Reduction of area	18.0	—
Modulus of elasticity	14,100,000	15,200,000
Brinell hardness	198	240

Higher values of ductility have been reported for titanium of equal strength, although none are known for Bureau of Mines titanium, and the modulus for bar stock is somewhat low. Tensile strength is comparable with that of cold drawn 1040 steel, and the yield ratio is high. The ductility is inferior to that of steel of equal strength.

Fatigue Properties — Sheet specimens were tested with as-rolled surfaces; the edges were cut with a circular milling cutter and were not finished subsequently. The other specimens were cross polished so as to remove scratches visible at 200 ×.

S-N curves for bar stock at 3500 r.p.m. (Fig. 1) gave a fatigue limit of 30,000 psi. The ratio of fatigue limit to tensile strength was 0.31, considerably lower than the 0.45 to 0.50 for heat treated steels, but about the same as for other nonferrous metals and alloys. [For reports of much higher fatigue limits obtained for melted and worked titanium, see p. 349 and 355.] Also shown in Fig. 1 are two tests on specimens having a notch calculated to produce about the maximum possible stress concentration factor for a notch of this radius in the size of specimen being used. If the calculated factor of 1.53 is accurate, the titanium specimens showed approximately complete notch sensitivity.

Alternating-torsion fatigue results for completely reversed stress cycles at 1450 cycles per min. are represented in Fig. 2; the fatigue limit is about 17,000 psi., which would mean a torsional fatigue ratio of 0.175 — rather low compared with 0.22 to 0.27 for most nonferrous metals and about 0.30 to 0.33 for heat treated steels.

*The views expressed are those of the authors, and not necessarily opinions of the Navy Department.

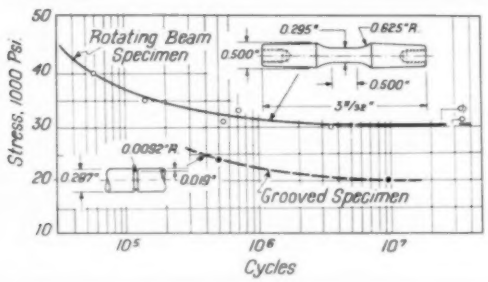


Fig. 1 — Flexural Fatigue of Titanium Bar Having a Tensile Strength of 98,000 Psi.

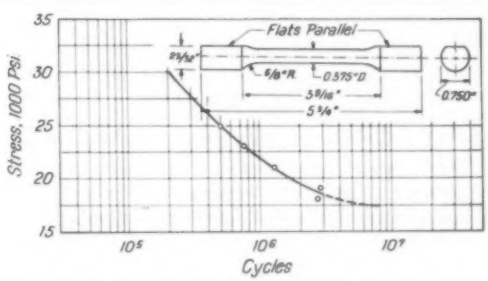


Fig. 2 — Alternating-Torsion Fatigue of Titanium Bar Having a Tensile Strength of 98,000 Psi.

Flexural tests of sheet specimens were made at 1725 cycles per min. The open points in Fig. 3 show that the fatigue limit was not reached at stresses as low as 20,000 psi. If the limit is estimated at 19,000 psi., the fatigue ratio would be 0.155, considerably lower than for any other known metal or alloy. Most investigators have obtained values around 0.3 in similar tests, although we know of one other test that gave results like our own.

Several of the sheet specimens developed fatigue cracks away from the milled edges. The cracks seemed not to be associated with any visible surface imperfection, and it was assumed that the sample — rather than the test procedure — was abnormal. Oil-powder and fluorescent powder tests and metallographic examination failed to reveal surface cracks, even when the sheet was flexed. As shown by the solid points in Fig. 3, stress relieving for 2 hr. at 400° F. caused a shift in the fatigue results at high stresses — but in the wrong direction.

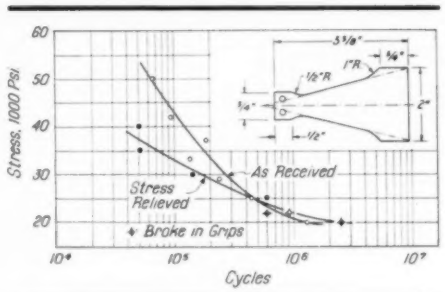


Fig. 3 — Flexural Fatigue of Titanium Sheet Having a Tensile Strength of 123,000 Psi.

Corrosion — Behavior of metals in salt water environments is of obvious importance to the Navy. Titanium sheet specimens (9 sq.in. exposed surface) were first suspended for 60 days in Severn River water (1/3 to 1/6 the salinity of sea water). The appearance of the specimens was unchanged and the weight increased by 0.0003 g. after both partial and complete immersion.

The next corrosion test, made in sea water (79° F.) at Kure Beach, N. C., was considerably more severe. It consisted of rotating a submerged disk 4.983 in. in diameter for 60 days at a speed of 1140 r.p.m. (a peripheral velocity of 25 ft. per sec.). The titanium disk lost about 0.1 g. in weight, and was unchanged in appearance, as shown in the upper part of Fig. 4. The lower part shows half of a cupro-nickel disk (70% copper, low iron content) run simultaneously. Cupro-nickel is considered one of the best commercial materials for resisting corrosion and erosion in salt water, and is commonly used for salt water piping and condenser tubing; however, the cupro-nickel disk lost 28.3 g. The severe eroding effect can be observed best in the outer area at the stencil markings; on the central area the film remained intact, and corrosion was little more than a light surface attack.

In a still more severe test, the specimen was mounted on a micarta disk, and rotated in sea water for 60 days at a peripheral velocity of 27 ft. per sec. With this apparatus the specimen must cut its own path through the water, which produces turbulent action that tends to erode the piece, especially at the leading edges. Two titanium specimens lost 0.003 and 0.006 mg. per sq.in. per day in this test but were unchanged in appearance.

Still another test, by jet impingement, was made for 30 days in sea water at 79° F. A titanium panel was placed 1/4 in. ahead of an 1/8-in. jet opening through which water was pumped at 12 ft. per sec. Air was introduced into the stream at 77 cu.cm. per min. The whole jet and specimen assembly was immersed in sea water. Results of duplicate tests showed no change in weight and no pitting; inspection failed to indicate which side was toward the jet.

One especially practical corrosion test was made in Severn River water to determine the resistance of the titanium bar stock to pitting attack or contact corrosion. Machined and sanded specimens were wrapped with four types of packing materials and immersed for 46 days. (18-8 and 13% chromium steel were run for comparison.) Two of these packing materials pitted both the stainless steels but not the titanium.

Titanium is not resistant to fouling organisms, and in this respect does not equal copper alloys in equipment handling sea water. Continuous movement of the water, treatment with chemicals or possibly with hot water would be necessary to prevent excessive fouling. So far, none of the titanium panels has shown corrosion of the metal beneath the fouling organisms.

Specimens of 1/8-in. titanium sheet exposed to seashore atmosphere rusted quickly, apparently because of iron picked up by the titanium during rolling. Such contamination should be avoided.

Special corrosion tests are being made in gas-water solutions at 500° F. Four pressure vessels have been constructed for the purpose, one of which is equipped to rotate the specimens in the water at 27 ft. per sec. Results are available for titanium in only one test, for 19½ days at 27 ft. per sec. in water saturated with oxygen at 500° F. and 700 psi. Weight losses are shown in Table I.

Other Properties — Thermal expansion of the titanium bar stock is as follows: Between 100 and 500° F., 5.05 micro-in. per in. per °F.; between 100 and 900° F., 5.15 micro-in. per in. per °F.

Attempts were made to spray-metallize with titanium wire. No difficulties in melting or atomizing the wire were encountered; however, the atomized metal was oxidized so rapidly that a suitable metallic deposit could not be obtained.

Machinability tests have not been conducted, but machinists report no particular difficulties in sawing, milling, turning, drilling, threading or polishing titanium when it is handled about like 18-8 stainless steel.

Possible Applications

In cold rolled titanium, adequate strength is found in unique combination with other valuable properties. In competition with stainless steels, the light weight of titanium can be an outstanding advantage. Compared with the light metals, corrosion resistance is pre-eminent. Against structural steels, corrosion resistance, lightness, and possibly ease of surface hardening may be controlling factors. Indeed, titanium appears to be important because it has some of nearly everything, and all in a metal exceedingly abundant in the earth's crust.

However, the outstanding resistance to corrosion in sea water is the property most attractive to the Navy. The corrosion tests made so far have scarcely damaged the metal at all; in several, very careful measurements had to be made to detect any effect whatever. No pitting occurred, and erosion was extremely slight in high-velocity water. In fact, titanium has resisted sea water better than any common engineering material. If — by using this light, strong, nonstrategic material — the Navy is able to multiply the life span of equipment now turning to rust, titanium may compete economically with materials now produced at far less cost per pound.

The resistance to salt water offers numerous possibilities for use on board ship. Condenser tubes operating with high water velocities are an example. Likewise, titanium has a good chance for application in lightweight piping systems handling salt water, especially those in which turbulent conditions downstream from fittings have been causing premature failure by erosion. Troubles with monel or stainless steel plumbing fixtures, particularly through pitting, might be eliminated by the use of titanium.

The superior resistance to pitting under packing materials indicates that titanium may serve well in pump rods or rotor shafts where stainless steel leaves much to be desired. Interest is high in the application to water-lubricated bearings, and steps have been taken to determine the usefulness of titanium, hardened by oxidation, in antifriction bearings of high load capacity, for operation in salt water.

Experiments are underway to determine the resistance to stack gases, with the object of using titanium wire for shipboard radio aerials. The metal may even be suitable for small, high-speed propellers if the resistance to hydraulic cavitation turns out as well as expected.

If further experiments bear out the results of preliminary tests, the Navy will be eager to use titanium.

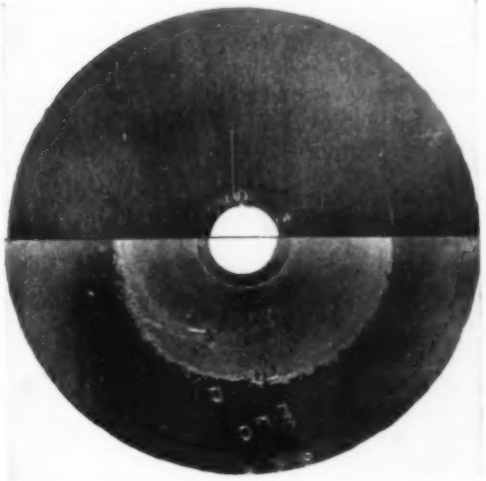


Fig. 4 — Disks of Titanium (top) and Cupro-Nickel (bottom) After 60 Days of Rotation in Sea Water at 1140 R.p.m. Observe erosion of stencil markings near outer edge of the cupro-nickel. × ⅔

Table I — Corrosion in Oxygenated Water at 500° F.

Material	Change in Weight	Appearance
Titanium No. 1	+0.0023 g.	Slight discoloration
Titanium No. 2	+0.0005	Slight discoloration
Zirconium	+0.0004	Slight discoloration
2S aluminum	−0.1693	Severely eroded
72S aluminum	−0.1738	Severely eroded
Cast beryllium	—	Failed intergranularly

ENGINEERING PROPERTIES OF SINTERED & ROLLED TITANIUM

By N. E. Promisel
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IN last month's *Metal Progress* (p. 186) we presented a brief summary of the titanium program of the Navy Bureau of Aeronautics. That program includes studies at the Naval Air Experimental Station, from which have come the preliminary data presented here.*

The titanium used in these experiments was obtained from the Federal Bureau of Mines. The powder was sintered and hot rolled, with only a small amount of cold rolling to improve the surface characteristics of the metal. The working schedule was selected so as to retain good workability in the sheet, even at a sacrifice in strength.

The designer is interested in strength, weight and rigidity relations for structural materials. Some of these relations are shown in Table I, for titanium, steel, and six light alloys.

Figure 1 (top) shows a tensile stress-strain curve for 0.064-in. titanium sheet. Elongation at fracture was 18%. Values for other tensile properties are shown on the graph and represent about the minimums for 0.064-in. sheet; compare, for instance, the following averages for longitudinal and transverse properties of various gages of cold worked sheet: tensile strength, 97,000 psi.; 0.2% yield strength, 85,000 psi.; proportional limit, 35,000 psi.; and elongation, 14% in 2 in. In general, the properties improve with decreasing thickness of sheet.

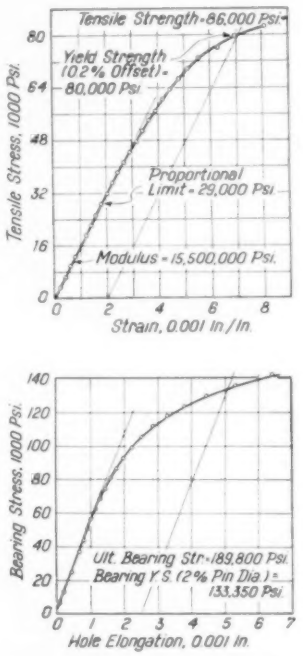


Fig. 1 — Stress-Strain Curves for Titanium

The average bearing strength of titanium sheet for all gages tested was about 200,000 psi. ultimate and 142,000 psi. yield. As would be expected, the bearing strength for specimens tested in the transverse direction was higher than for specimens tested longitudinally. Minimum values obtained for 0.064-in. sheet are shown in Fig. 1 (bottom); in this test the pin diameter was ⅛ in., ratio of pin diameter to thickness was 1.95, and edge distance was ¼ in. Thinner sheets have somewhat higher bearing strength.

Figure 2 shows a typical column curve for 0.064-in. titanium sheet. Titanium is similar to 75S-T aluminum; both metals break away from the Euler curve at about 40,000 psi.; however,

*The author acknowledges the assistance of personnel of the Naval Air Experimental Station and of Mr. H. J. Boertzel, Bureau of Aeronautics, in preparing this article.

Table I — Comparison of Approximate Structural Properties and Parameters of Selected Laboratory and Commercial Alloys

Material	Density, D, G./Cu.Cm.	Modulus, E, Psi	Tensile Strength, Psi.	Compressive Yield, Psi.	Comparisons With 24S-T = 100%*				
					T.S./D	C.Y.S./D	E/D²	E/D³	E/D
24S-T Aluminum	2.8	10.5×10^6	62,000	40,000	—	—	—	—	—
75S-T Aluminum	2.8	10.5	75,000	65,000	+21%	+ 62%	0	0	0
65 Al – 35 Be Sheet	2.4	20	75,000	50,000	+39	+ 44	+194%	+154%	+55%
Mg – 0.6 Zr	1.8	6.5	54,000	32,000	+33	+ 22	+121	+ 45	— 6
AZ31 Magnesium	1.8	6.5	39,000	24,000	— 4	— 6	+121	+ 45	— 6
Mg-Li Alloy†	1.6	6.5	50,000	45,000	+34	+100	+176	+ 85	+ 7
Titanium Alloy‡	4.5	16	150,000	130,000	+47	+104	— 65	— 41	— 7
4340 Steel	7.9	30	220,000	200,000	+24	+ 76	— 88	— 65	0

*Percentage increase or decrease with reference to 24S-T as 100%. †This alloy contains approximately 14% lithium, 15% cadmium, 5% silver, the remainder essentially magnesium. ‡Values for a dilute titanium alloy having ductility comparable with that of the other alloys in this table.

titanium has a steeper curve thereafter, indicating greater stability for the smaller values of slenderness ratio. Although in this curve titanium shows no significant advantage over aluminum alloy, titanium is subject to much potential improvement by alloying; in any event, the advantages of titanium increase as the temperature increases.

The results of preliminary flexural fatigue tests on sheet are shown in Fig. 3, for 0.032-in. sheet rolled from sintered compacts. The fatigue limit of 25,000 psi. is less than would be expected from metal having the high static strength of rolled titanium; the difference may be the result of using transverse specimens. (Quite a different result was obtained for titanium bars made by casting and rolling, and furnished us by the Remington Arms Co. The fatigue limit of this bar stock is 68,000 psi., an unusually high figure of about 70% of the static tensile strength.★)

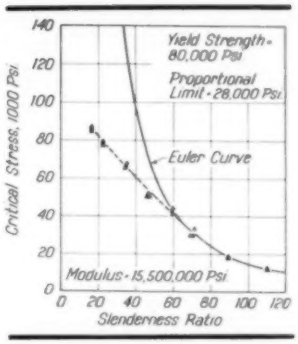


Fig. 2 — Column Curve for Titanium Sheet

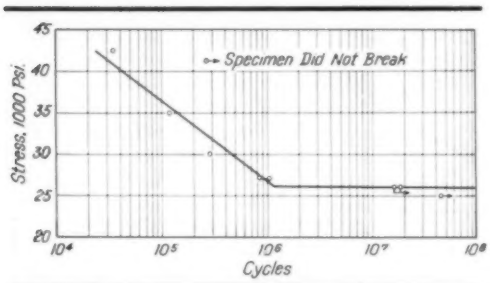


Fig. 3 — Flexural Fatigue of Titanium Sheet Having a Tensile Strength of 100,000 Psi.

Considerable difficulty was experienced because of the severe heating of specimens during the fatigue test; the specimens were cooled by directing a stream of air on them during the test.†

★Editor's Note: In discussion, H. C. Cross reported a fatigue limit of 65,000 psi., obtained at Battelle in rotating-beam tests of titanium bar (arc melted and rolled) of tensile strength 100,000 psi.

†Editor's Note: As a general comment on the fatigue results reported from various laboratories at the symposium, one discusser suggested that in future it would be desirable to record the hardness, tensile strength and proportional limit of the material both before and after testing.

The results of dimpling tests and bend tests on sheet, as well as upsetting tests on ⅛-in. rod (all at room temperature), were generally unsatisfactory, indicating that the cold formability of sintered and rolled titanium is poor. Data for hot dimpling and forming have not been developed.

Spot Welding — Tests were made to determine the spot-welding characteristics and machine settings for welding several gages of titanium sheet, using stored-energy equipment. In Fig. 4, the results are plotted as bands; the lower part of each band represents specimens that were simply degreased, and the upper part represents specimens that were pickled in HF after degreasing. A dome tip having a radius of 6 in. and a constant electrode force of 880 lb. were used to weld all specimens. This electrode force was selected so as not to exceed the strength of the offset electrodes required by the design and shape of certain parts of a titanium seaplane float that was to be spot welded. The results of these tests indicate that metallurgically sound spot welds with satisfactory shear properties may be obtained using stored-energy equipment and fairly high electrode forces.

In Conclusion — All the data presented here are based on unalloyed titanium produced about a year ago. Greatly improved titanium alloys are now in prospect, and plans have been made by the Bureau of Aeronautics for developing the technology of titanium on a larger scale.

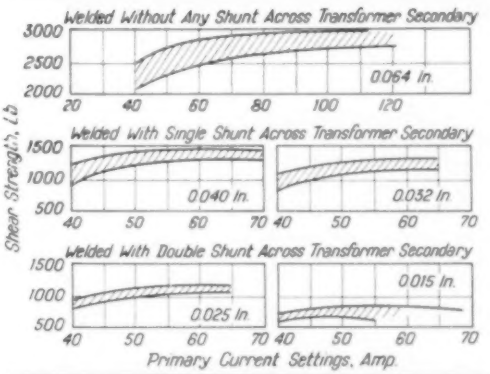


Fig. 4 — Strength of Welds in Titanium Sheet

MECHANICAL PROPERTIES OF WROUGHT TITANIUM ALLOYS MADE BY ARC MELTING OR BY SINTERING

By Howard C. Cross
Battelle Memorial Institute
Columbus, Ohio

SOME of the titanium alloys investigated at Battelle have been made by powder metallurgy methods and some by the arc-melting techniques described in last month's *Metal Progress*, p. 197. Both magnesium-reduced titanium powder, as produced by the Bureau of Mines, and high-purity iodide titanium have been used for the base metal.

No quantitative measurements have been reported previously concerning the effects of oxygen, nitrogen, and hydrogen on the strength and ductility of titanium. One reason for this was the unavailability of titanium pure enough to be considered a good base-line material; also, no reliable analytical methods exist for the determination of these gases — particularly oxygen — in titanium.

Alloys of titanium and oxygen, nitrogen or hydrogen were made at Battelle by adding known volumes of the gases to an evacuated system within which wire specimens of iodide titanium were suspended.* The wire was heated to between 1290 and 1830° F. for the time interval required to obtain absorption of the gases by the metal, and then uniform diffusion of the gases throughout the metal. Absorption of oxygen was rapid and complete. With hydrogen, the specimen temperature had to be lowered to between 1200 and 1290° F. to obtain complete absorption. Nitrogen diffused so slowly that, after complete absorption, specimens were heated to 2000° F. for homogenization.

*The composition and properties of this high-purity titanium are described on p. 346.

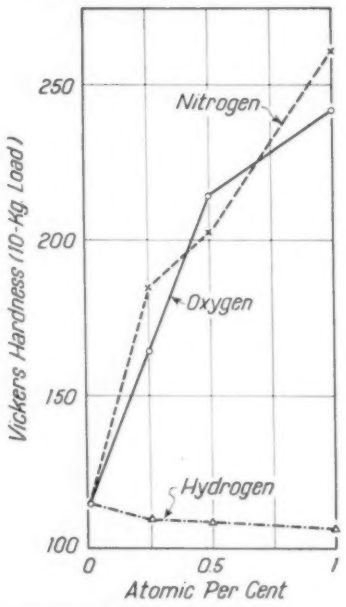


Fig. 1 — Average Cross-Sectional Hardness Values for Alloys of Iodide Titanium With Oxygen, Nitrogen and Hydrogen

"Zero" or base-line samples of titanium containing no gas were prepared using fresh samples of iodide titanium under similar heating cycles in an evacuated system. The alloy compositions investigated were 0.25, 0.50 and 1 atomic % additions each of oxygen, nitrogen and hydrogen.

Oxygen refines the structure of titanium, making the plates of alpha-titanium smaller and the Widmanstätten arrangement more regular. Nitrogen promotes the formation of needles of alpha-titanium. The structures of the hydrogen alloys are not much different from unalloyed titanium.

Hardness and tensile tests were made on the various alloys; the hardness data are shown in Fig. 1. Data for the oxygen and nitrogen alloys are somewhat erratic, but indicate that oxygen and nitrogen harden titanium to about the same extent, with nitrogen possibly having the greater effect. Hydrogen up to 1 atomic % (0.021 weight %) does not increase the hardness of iodide titanium, and seems actually to decrease it slightly; however, the apparent decrease may have been caused by hardness variations in the original iodide titanium.

Figure 2 shows the effect of the gaseous additions on the tensile strength and elongation of iodide titanium. Nitrogen has a considerably greater strengthening effect than oxygen, and decreases the ductility to a greater extent. Hydrogen seems to have a slight strengthening effect, but this indication may be the result of variations in the initial material. Nitrogen

is more deleterious to cold rollability than oxygen; hydrogen has only a slight effect on the work hardening of titanium.

Similar experiments on the effects of oxygen and nitrogen have been made for arc-melted titanium prepared from powder produced either by the Bureau of Mines or by Battelle. In arc melting, oxygen was added as titanium dioxide and nitrogen as titanium nitride. Table I shows the mechanical properties.

Unfortunately the titanium powder used in preparing these melts was gassy and every heat was contaminated with tungsten. The data indicate substantial increases in strength and hardness for these melts with intentional additions of oxygen and nitrogen, but it is not proper to ascribe the effects to the gaseous elements alone, because of the indeterminate effect of tungsten. However, most of the strengths in Table I are considerably in excess of those usually associated with the small tungsten contents indicated.

Table I shows also the effect of carbon additions to arc-melted titanium. As with oxygen and nitrogen, the effect of carbon is clouded by tungsten contamination, but the data show a high level of strength and ductility in a titanium alloy containing both carbon and tungsten. There are no indications that carbon in moderate amounts is detrimental.

In some early work for Project RAND (U. S. Air Force contract) a broad screening of titanium alloys prepared by powder metallurgy techniques with up to 50% of the high-melting metals chromium, molybdenum, tungsten, columbium and tantalum was conducted. These five metals, along with titanium itself, are the most important and potentially plentiful metals having higher melting points than iron, nickel and cobalt, the metals on which present commercial high-temperature alloys are based. The results obtained at that time indicated that the compositions of interest for engineering properties lay below the 20% addition level. Since the initial survey work, a more intensive investigation of the binary alloy range from 0 to 10% additions has been made. The data are summarized in Fig. 3.

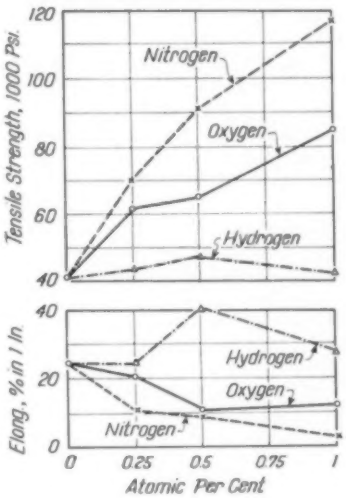
Molybdenum, tungsten, columbium and tantalum, in amounts up to 20%, increase the tensile and yield strengths progressively. The first additions of chromium have the same effect, but the

Table I — Effect of Oxygen, Nitrogen and Carbon on Properties of Arc-Melted and Hot Forged Titanium

Alloy Composition, %	Rockwell C Hardness	Tensile Strength, Psi.	Elongation in 1 In., %
Arc-melted titanium	19	95,000*	25
0.14 O, 0.11 N, 0.3 W	31	112,000	1.5
0.25 O, 2.23 W	40	168,000	0.5‡
0.67 O, 0.16 N, 0.24 W	42	160,000	0.5
0.15 N, 1.41 W	34	145,800	2.5
0.29 N, 1.88 W	31	169,400	3.5
0.46 N, 1.69 W	45	191,400	0
0.15 C, 1.5 W	27	130,800†	21
0.25 C, 2.5 W	35	147,000‡	10
0.39 C, 3.8 W	31	169,000	11

*Yield strength, 80,000 psi. †Yield strength, 117,600 psi. ‡Yield strength, 129,800 psi. §Defective bar may have influenced measured ductility.

Fig. 2 — Tensile Strength and Elongation of Alloys of Iodide Titanium With Oxygen, Nitrogen and Hydrogen



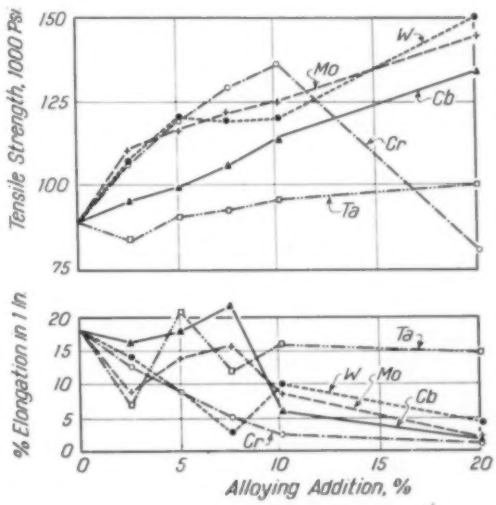


Fig. 3 — Effects of Chromium, Molybdenum, Tungsten, Columbium and Tantalum on the Tensile Strength and Elongation of Titanium. All alloys were prepared by the pressing and sintering methods of powder metallurgy, then hot rolled at 1650° F. and furnace cooled.

20% chromium alloy was weaker, because of the excessive amount of intermetallic compound present. Chromium, molybdenum and tungsten of Group VI-A of the periodic table strengthen titanium more than columbium and tantalum of Group V-A. The strength levels attained even with additions of 20% of the alloying elements in these alloys prepared by powder metallurgy methods are not so high as those shown by arc-melted alloys having less than 4% tungsten and with additions of oxygen and nitrogen. The greatest usefulness of chromium, molybdenum and tungsten additions may well be in combination with other alloying elements. The tensile properties of ternary alloys of chromium, molybdenum or tungsten with titanium are slightly better than those of the binary alloys with equivalent alloy content.

The most ductile binary alloys, as indicated by elongation in the tensile test, were tested for their work hardening characteristics, and the data are shown in Fig. 4. The rate of work hardening of these alloys is about the same as, or slightly less than, that of unalloyed titanium. Results of tensile tests on the alloys cold rolled to 50% reduction in thickness are given in Table II. The properties of the same alloys in the original hot rolled and furnace cooled condition are included also.

In the work at Battelle on arc-melted alloys, gas evolution from the titanium powder during melting sometimes results in considerable spattering, with resultant tungsten contamination from the tungsten-tipped electrode in some alloys, and ingot defects in others. Despite these difficulties, which made an accurate evaluation of alloy additions difficult, nearly all the elements that were studied hardened and strengthened titanium. Some of the more interesting alloy compositions and their tensile strengths, elongations and hardnesses, based on individual bar values, are as follows:

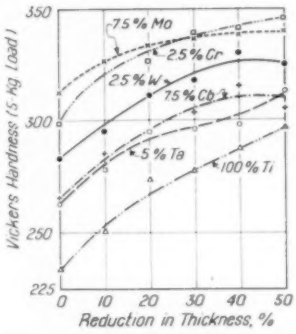


Fig. 4 — Work Hardening Characteristics of Titanium Alloys Prepared by Methods of Powder Metallurgy. Initial condition was hot rolled and furnace cooled.

1. 0.4% C, 3.8% W, hot forged: 169,000 psi. tensile strength, 11.5% elongation, Rockwell C-32.

2. 0.5% oxygen (intended composition), 2.04% W, after heating at 1750° F. and water quenching: 167,500 psi. tensile strength, 4.5% elongation, Rockwell C-43.

3. 0.3% N, 1.88% W, hot forged: 169,500 psi. tensile strength, 3.5% elongation, Rockwell C-31.

4. 0.6% N, 0.13% W, after heating at 1750° F. and water quenching: 155,000 psi. tensile strength, 7% elongation, Rockwell C-38.

5. 4.7% W (gas content not determined), hot forged: 198,000 psi. tensile strength, 2% elongation.

6. 5.0% Cr, 0.25% C (intended), 0.01% W, 0.063% N: 171,000 psi. tensile strength, 2% elongation, Rockwell C-41.

These tests confirm the beneficial effects of carbon, oxygen, nitrogen, molybdenum, tungsten and chromium. Much more work is needed to investigate thoroughly alloys of titanium with these and other elements.

Additional work is now in progress for Wright-Patterson Air Force Base on determining the effect of alloying additions to titanium of chromium, molybdenum, nickel, copper, lead, magnesium, silicon, manganese, vanadium, iron and cobalt. Hemispherical ½-lb. ingots 2 in. in diameter are being made by arc melting of titanium powder. The ingots are being forged and rolled to 0.064-in. sheet. Tensile strength, hardness, cold bending characteristics and response to heat treatment will be investigated.

Table II — Changes in Tensile Properties of Titanium Alloys on Cold Rolling to 50% Reduction in Thickness*

Composition, %	Hot Rolled and Furnace Cooled				Cold Rolled to 50% Reduction			
	Tensile Strength, Psi.	Yield Strength (0.2% Offset), Psi.	Elongation in 1 In., %	Modulus of Elasticity, Million Psi.	Tensile Strength, Psi.	Yield Strength (0.2% Offset), Psi.	Elongation in 1 In., %	Modulus of Elasticity, Million Psi.
100 Ti	89,000	66,000	18	16.4	128,000	119,000	4	14.9
97.5 Ti, 2.5 Cr	107,000	85,000	13	16.6	148,000	133,000	2	15.3
97.5 Ti, 2.5 W	108,000	—	14	—	140,000	133,000	1	15.3
92.5 Ti, 7.5 Cb	106,000	86,000	22	15.2	139,000	120,000	3	14.6
95 Ti, 5 Ta	91,000	69,000	21	15.7	131,000	116,000	4	15.5

*All alloys prepared by powder metallurgy. Test specimens parallel to rolling direction and 3 in. long with gage lengths 1 in. long and 0.25 in. wide. Tensile specimen of the alloy containing 92.5% titanium, 7.5% molybdenum was defective.

PROPERTIES OF BINARY SINTERED & ROLLED TITANIUM ALLOYS

By E. I. Larsen, E. F. Swazy, L. S. Busch and R. H. Freyer
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THIS PAPER summarizes development work in the metallurgical research department of P. R. Mallory & Co., under contract with the Navy Bureau of Aeronautics.* The purpose of this work was to determine whether titanium alloys exhibited physical and mechanical properties superior to known metals and alloys. The project has been entirely exploratory and, in general, has been confined to alloys containing more than 90% titanium.

The preliminary results reported here include principally data on mechanical properties and electrical resistivity of alloys in the hot rolled, cold rolled and annealed conditions. A few qualitative observations were made also on the resistance to oxidation, formation of low-melting phases, and the ease with which the alloys could be hot and cold worked.

Preliminary results of vacuum melting in a graphite crucible indicated a variable carbon pickup ranging from about 0.5 to 1.5%, which was complicated further by segregation of the alloying additives. In order to eliminate these variables, it was decided to fabricate all alloys (with one or two exceptions) by powder metallurgy methods.

Materials — The titanium powder used in all alloys was supplied by the Bureau of Mines from one master lot. This lot of powder had the following size distribution: 8.0% through 200 mesh, 20.0% through 100 mesh, 41.6% through 60 mesh, and 99.9% through 30 mesh. The chemical composition was as shown in Table I. All of the alloying elements were of the highest purity that could be obtained commercially.

Preparation of Alloys — Powder mixtures were compacted at a pressure of 30 tons per sq.in. The resulting flat bars, semirounds or buttons were sintered for 1 hr. at 2200° F. in a vacuum of less than one micron. Sintered specimens were either cold rolled with intermittent anneals in vacuum, or encased in a steel sheath and hot rolled at 1475° F. Certain specimens were both hot rolled and cold rolled.

*The interest and advice of Mr. N. E. Promisel of the Bureau of Aeronautics have been invaluable. Appreciation is expressed also for the technical assistance of Dr. R. S. Dean, metallurgical consultant.

Table I — Chemical Composition of Titanium Powder

Element	Weight %
Magnesium	0.27
Iron	0.06
Aluminum	0.01
Silicon	0.02
Copper	None
Manganese	None
Chlorine (as chloride)	0.23
Hydrogen*	0.0948 to 0.1110
Nitrogen*	0.024 to 0.035
Oxygen*	0.058 to 0.072

*Analyzed by W. A. Peifer of the Carnegie Institute of Technology.

The alloys will be discussed in the order in which the alloying elements appear in the vertical columns of the Periodic Table. Data on properties are listed in the same order in Table II, p. 361.

Titanium-Hydrogen — Above 930° F. hydrogen combines with titanium to form the hard and brittle hydride. However, if specimens sintered in oxygen-free hydrogen are cooled in a vacuum from 1830°F., ductile material can be produced.

Titanium-Beryllium — It was necessary to use −150 mesh beryllium powder and to mix it intimately with titanium to prevent segregation and localized melting during sintering. Sintering at 2200° F. was satisfactory for the 0.5% alloy but higher beryllium contents required lower sintering temperatures and longer time. An alloy containing 3% beryllium melted at 1785° F. and the 10% beryllium alloy melted at 1740° F. Sintered alloys up to 1% beryllium were cold rolled as much as 50% before annealing.

Titanium-Boron — Boron in amounts of 0.1, 0.5 and 5% was added to titanium, and bars pressed from the powders were sintered satisfactorily at 2200° F. A spectrographic analysis of the boron powder used indicated about 94% boron with about 4% magnesium as the primary impurity. The sintered bars of 0.1 and 0.5% boron were cold rolled as much as 45% before vacuum annealing and then were cold rolled an additional 49 to 58%. The 5% boron sintered bars could not be cold rolled appreciably without serious cracking. The electrical resistivity of these alloys, both cold rolled and vacuum annealed, was 58 microhm-cm., the lowest value obtained for any titanium alloy.

Titanium-Aluminum — A 10% aluminum alloy contained a considerable amount of a second phase high in aluminum and the aluminum contents were thereafter held at 1 and 3%. Both these alloys responded normally to sin-

tering at 2200° F. and were hot rolled readily at 1475° F. to reductions of 77%. The most noteworthy features of the aluminum-titanium alloys are their ability to be hot and cold worked and their greatly increased resistance to oxidation in comparison with pure titanium.

Titanium-Indium — All titanium-indium alloys were prepared by mixing a −100 mesh powder with the titanium powder. If the powders were coarser than this, segregation occurred. Alloys containing up to 5% indium were prepared. About two thirds of the indium added was volatilized during sintering. Microstructures indicated that the alloys were single-phase regardless of the heat treatment.

Titanium-Carbon — The titanium-carbon alloys were made by melting titanium in a graphite or carbon crucible. Such ingots contained from 0.5 to 1.5% carbon. An ingot containing 1.28% carbon was hot rolled 77% and, after annealing, was cold swaged an additional 19% before serious cracking occurred. Ductility probably depends on how well massive carbides are broken up during working.

Titanium-Silicon — The 3 and 10% silicon compositions melted during vacuum sintering at 2235 and 2000° F., respectively. Bars with 0.5 and 1.0% silicon were sintered satisfactorily at 2200° F. The 1% alloy was cold rolled to a total reduction of 79.7% by alternate reductions of 26 and 34% and vacuum annealing for 1 hr. at 1830° F. without appreciable cracking until the final reduction (38%). The 0.5% silicon alloy was readily cold rolled 55%, both as sintered and as vacuum annealed, without cracking appreciably.

Titanium-Zirconium — Alloys with 10, 20, 30 and 40% zirconium were vacuum sintered 1 hr. at 2200° F. and hot rolled 77% at 1475° F. in steel tubes. In some alloys, small craters formed on the surface when comparatively large pieces of sponge zirconium were used. The microstructures of the hot rolled alloys show a two-phase banded structure, indicating undiffused zirconium.

Titanium-Nitrogen — Nitrogen combines with titanium to form a hard and brittle nitride, but apparently the nitride will not form readily if there is any free oxygen present in the atmosphere.

Titanium-Vanadium — A 95% grade of lump vanadium was crushed to about 30 mesh, mixed with titanium in amounts of 0.5, 5 and 15%, pressed into bars and vacuum sintered for 1 hr. at 2200° F. No depression in melting point was observed. The 15% vanadium sintered bar could not be cold rolled appreciably. However, the 0.5 and 5% alloys were cold rolled to reductions of 25 to 58% without serious edge cracking.

Titanium-Oxygen — Oxygen combines with titanium at comparatively low temperatures to form oxide films that destroy the ductility if the penetration is great enough. The oxide is not adherent and usually spalls off readily from large, dense specimens. The titanium powder, as received from the Bureau of Mines, contained between 0.058 and 0.072% oxygen. A series of oxygen analyses made on the powder, on sintered and hot rolled specimens, and on hot rolled specimens heated in air at 1560° F. indicated that the powder contained far more oxygen than the fabricated specimens, which analyzed from 0.0007 to 0.0079% oxygen.

Titanium-Chromium — A bar with 10% chromium melted partially during an attempt to vacuum sinter it at 2200° F., but this alloy was sintered satisfactorily at 2055° F. with a shrinkage of 3%. The sintered bar was cold rolled 26% and vacuum annealed 1 hr. at 1830° F. Annealing did not soften the bar, and it could be reduced only 9% more. The hardness was Rockwell A-62½ (Rockwell C-24) and the resistivity was 93 microhm-cm.

Titanium-Molybdenum — Alloys containing 10 and 20% molybdenum were vacuum sintered satisfactorily during 1 hr. at 2200° F. with shrinkage varying from 2 to 4%, but the 30 and 40% alloys could not be sintered satisfactorily because of expansion, bending and cracking. A specimen with 10% molybdenum was cold rolled 68%, and rods of 10 and 20% molybdenum were hot rolled 77% at 1475° F. The resistivity measurements are consistent with a complete solid solubility of titanium and molybdenum, showing a maximum resistivity at about 20% molybdenum.

Titanium-Tungsten — A bar of 10% tungsten was vacuum sintered satisfactorily during 1 hr. at 2200° F.; the bar shrank 8%. The sintered bar was cold rolled 21% and vacuum annealed 1 hr. at 1830° F. Annealing lowered the hardness from Rockwell A-67 (Rockwell C-33) to Rockwell A-62½ (Rockwell C-24). The annealed bar was cold rolled 10% more and the resistivity was 87 microhm-cm.

Titanium-Manganese — Alloys of titanium with 3.53 to 14.88% manganese were sintered and worked successfully. Alloys containing up to 40% manganese were prepared but could not be sintered successfully because of expansion and warpage. As much as 50% loss of manganese occurred during sintering. An alloy with an intended composition of 10% manganese analyzed only 0.26% manganese after being melted in a graphite crucible. The powders used for making the pressed bars segregated badly during mixing and this segregation was noticeable in microstructures of some hot rolled specimens. Wet mixing improved this condition but did not eliminate it. The best powders available for mixing contained as much as 1% oxygen. However, oxygen analyses of alloys made from such powders showed less oxygen than was present in the titanium powder used to make

them. Microstructures of sintered and worked alloys indicated a decided difference depending on the thermal history. Both cooling rate after hot rolling and after annealing, and segregation of manganese affected the properties. Quenched alloys usually were harder than the same alloys slowly cooled but the difference was not always consistent, particularly in alloys containing more than 6% manganese. Electrical resistivity can be controlled over a range of 80 to 120 microhm-cm. by controlling manganese content and heat treatment.

Titanium-Iron — A bar with 10% iron was sintered in a vacuum for 1 hr. at 2200° F. with normal shrinkage. The sintered bar was cold rolled 14½% and vacuum annealed 1 hr. at 1830° F. The annealed bar could be cold rolled only 5% further.

Titanium-Cobalt — Attempts to vacuum sinter a 10% cobalt alloy at 2200° F. were unsatisfactory because of melting. Sintering at 2055° F. was unsatisfactory because of the formation of blisters on the specimens. Sintering at 1920° F. produced a satisfactory specimen which shrank approximately 3%. The sintered bar was cold rolled 15% and vacuum annealed 1 hr. at 1830° F. The annealed bar could not be cold rolled more than 1% further because of surface cracking. Approximately 10% cobalt depresses the solidus to 2200° F.

Titanium-Nickel — A bar with 10% nickel was vacuum sintered 1 hr. at 2200° F. with about 2% shrinkage. The sintered bar could not be cold rolled more than 6%.

Summary — The following alloying additions to titanium may be of practical value: up to 5% aluminum, about 5% manganese, up to 1% beryllium, up to 1% boron, up to 1% silicon. Various titanium alloys are now being made by melting in graphite, either in a vacuum or in purified argon. This work is being done under contract with the Bureau of Aeronautics, U. S. Navy Department.

Table II — Mechanical Properties and Electrical Resistivity of Titanium and Some Binary Sintered and Rolled Titanium Alloys

Composition, %		Condition*	Rockwell		Tensile Strength, Psi.	Elongation, %	Electrical Resistivity, Microhm-Cm
Intended	Analyzed		A	C			
		Unalloyed Titanium†					
100 Ti	—	H.R. 77%	62½	24	100,000	7.8 (2 in.)	60
100 Ti	—	H.R. 77%, Ann. 1560	62	23	90,700	9.5 (2 in.)	60
100 Ti	—	H.R. 77%, C.S. 52%	61	21	147,000	0	62
		Titanium-Beryllium Alloys					
0.5 Be	—	H.R. 77%	65	29	115,200	7.8 (2 in.)	64
0.5 Be	—	C.R. 73%	67	33	141,000	3 (1 in.)	—
0.5 Be	—	C.R. 90%	66	31	142,300	2.4 (2 in.)	—
0.5 Be	—	H.R. 77%, Ann. 1830	61½	22	107,700	7.8 (2 in.)	67
0.5 Be	—	C.R. 73%, Ann. 1830	61½	22	100,000	9.5 (2 in.)	65
0.5 Be	—	C.R. 90%, Ann. 1830	56	—	86,000	6.2 (2 in.)	67
1 Be	0.37 Be	C.R. 70%	64	27	115,000	3.2 (1 in.)	—
1 Be	0.37 Be	C.R. 71%	67	33	124,700	3 (1 in.)	—
1 Be	0.37 Be	C.R. 70%, Ann. 1830	59	—	93,000	25 (1 in.)	—
1 Be	0.37 Be	C.R. 71%, Ann. 1830	61	21	103,000	12.5 (1 in.)	66
1 Be	1.07 Be	H.R. 77%	61	21	96,000	4.5 (2 in.)	62
1 Be	1.07 Be	1830° F., W.Q.	69	37	151,000	3 (1 in.)	75
1 Be	1.07 Be	1830° F., S.C.	57	—	82,500	3 (1 in.)	67
1 Be	1.07 Be	1560° F., W.Q.	61	21	101,500	6.2 (1 in.)	68
1 Be	1.07 Be	1560° F., S.C.	53	—	68,500	6.2 (1 in.)	61
		Titanium-Boron Alloys					
0.1 B	—	C.R. 76½%	66	31	130,000	3 (2 in.)	—
0.1 B	—	C.R. 76½%, Ann. 1830	60	19	99,700	9.4 (2 in.)	58
0.5 B	—	C.R. 72%	67	33	139,000	3 (2 in.)	—
0.5 B	—	C.R. 72%, Ann. 1830	63	25	114,400	6.5 (2 in.)	58
		Titanium-Aluminum Alloys					
1 Al	0.33 Al	H.R. 77%	65	29	106,500	6.2 (2 in.)	78
1 Al	0.33 Al	H.R. 77%, Ann. 1560	63	25	91,400	12.5 (2 in.)	—
1 Al	0.33 Al	H.R. 77%, C.S. 65%	65	29	159,000	3 (2 in.)	77
3 Al	2.64 Al	H.R. 77%	66	31	118,000	6.2 (2 in.)	130
3 Al	2.64 Al	H.R. 77%, Ann. 1560	66	31	109,000	7.8 (2 in.)	—
3 Al	2.64 Al	H.R. 77%, C.S. 65%	67	33	155,000	3 (1 in.)	125
		Titanium-Indium Alloys					
3 In	0.98 In	H.R. 76%	63	25	110,000	4.7 (1 in.)	85
3 In	0.98 In	H.R. 76%, Ann. 1830	63	25	106,800	12.5 (2 in.)	—
3 In	0.98 In	C.R. 73%	67	33	132,500	0	99
3 In	0.98 In	C.R. 73%, Ann. 1830	60½	20	100,000	7.8 (2 in.)	—
		Titanium-Carbon Alloys (Prepared by melting)					
—	1.28 C	H.R. 77%, C.S. 19%	63	25	137,000	4.6 (2 in.)	61
—	1.28 C	H.R., C.S., Ann. 1290	—	—	114,500	8.3 (2 in.)	—
—	1.18 C	H.S. 88%	—	—	104,600	12.5	—
—	1.18 C	H.S. 88%, Ann. 1290	—	—	96,700	19	—
		Titanium-Silicon Alloys					
0.5 Si	—	C.R. 80%	67	33	126,000	1.5 (2 in.)	74
0.5 Si	—	C.R. 80%, Ann. 1830	62	22	115,300	9.4 (2 in.)	61
1 Si	1.06 Si	C.R. 80%	71	41	160,800	1.5 (2 in.)	102
1 Si	1.06 Si	C.R. 80%, Ann. 1830	64	27	113,700	4.3 (2 in.)	88
		Titanium-Zirconium Alloys					
10 Zr	—	H.R. 77%	68	35	130,000	3 (2 in.)	76
20 Zr	—	H.R. 77%	69	37	104,000	3 (2 in.)	80
30 Zr	—	H.R. 77%	69	37	74,500	1.5 (2 in.)	94
40 Zr	—	H.R. 77%	73	45	49,000	0	115
		Titanium-Vanadium Alloys					
0.5 V	—	C.R. 77%	66	31	130,500	3 (2 in.)	—
0.5 V	—	C.R. 77%, Ann. 1830	61	21	98,700	12.5 (2 in.)	73
5 V	4.06 V	C.R. 82%	68	35	153,000	0	87
		Titanium-Molybdenum Alloys					
10 Mo	10.21 Mo	H.R. 77%	66	31	—	—	—
10 Mo	10.21 Mo	H.R. 77%, Ann. 1560	62	23	110,000	0	80
20 Mo	12.52 Mo	H.R. 77%	68	35	—	—	—
20 Mo	12.52 Mo	H.R. 77%, Ann. 1560	66	31	135,000	3.9	98
		Titanium-Manganese Alloys					
—	3.53 Mn	C.R. 70.7%	70	39	—	—	—
—	3.53 Mn	C.R. 70.7%, Ann. 1830	68	35	147,000	3 (1 in.)	88
—	4.30 Mn	H.R. 77%	69	37	—	—	—
—	4.30 Mn	H.R. 77%, Ann. 1830	66	31	138,000	9.4 (2 in.)	93
—	5.62 Mn	H.R. 77%	69	37	164,000	4.5 (2 in.)	116
—	6.02 Mn	H.R. 77%	69	37	—	—	—
—	6.02 Mn	H.R. 77%, Ann. 1830	68	35	101,000	0	105
—	7.22 Mn	H.R. 77%	69	37	—	—	—
—	7.22 Mn	H.R. 77%, Ann. 1830	69	37	164,500	0	118
—	13.00 Mn	H.R. 77%	72	43	—	—	—
—	13.00 Mn	H.R. 77%, Ann. 1830	64	27	141,000	6 (2 in.)	—

*H.R. = hot rolled, C.R. = cold rolled, Ann. = annealed (annealing temperature given in °F.), W.Q. = water quenched, S.C. = slowly cooled, C.S. = cold swaged, H.S. = hot swaged.
†Results of chemical analysis on the original powder are given in Table I, p. 359.

HIGH-TEMPERATURE PROPERTIES OF TITANIUM ALLOY CASTINGS

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OUR INTEREST in titanium has been founded on the hope that titanium alloys might prove useful as structural materials in rotating and reciprocating machines operating at high temperature.

The light weight of titanium (4.5 g. per cu.cm.) would be an obvious advantage in moving parts. However, titanium and its dilute alloys are disappointingly weak above 800° F., although the ductility is spectacularly high. [See, for instance, Fig. 3 on page 349.] Also, the resistance of titanium to oxidation is not favorable at high temperatures. The metallurgical problem, then, is to increase the high-temperature strength and stability of titanium without increasing the density too greatly.

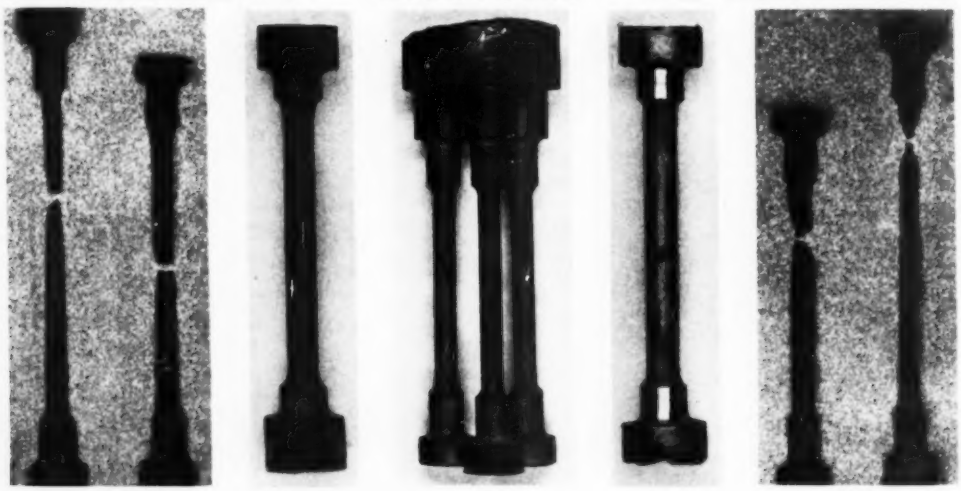
By adding from 30 to 50% (or even more) of high-melting metals to titanium, we have produced alloys that compare favorably in strength with conventional high-temperature materials and are considerably lighter. All of our high-temperature tests have been made on castings, produced in the form of tensile specimens *(see cut)*.

Magnesia Mold

Cast Tensile Specimens

The metal was melted and cast in a vacuum or an inert atmosphere, as described in last month's *Metal Progress*, p. 196. After the excess metal had been trimmed from these castings, the fillets under the heads were ground concentric with the central portion of the specimen *(see cut)* so that the gage length would be as nearly axial as possible with the applied load during the tensile test.

Most of the data on mechanical properties were obtained in a screw-driven tensile machine developed by A. Nadai and M. J. Manjoine (see *Metal Progress* for November 1946). Creep-rupture data are shown in Table I, and results of



Fractured | Trimmed | As Cast | Ground | Fractured

constant-strain-rate tests in Table II. The latter data were obtained with a strain rate of 0.5 per hr.

Nearly all of our alloys contained from 20 to 40% chromium. The best yield strengths were observed for titanium-chromium-base alloys containing molybdenum and tungsten in 4-to-1 atomic ratio; molybdenum and tungsten together seem to have a greater strengthening effect than either element separately in the titanium-chromium alloys.

Although many of the titanium alloy castings are very ductile at high temperature, they are brittle when cold. This may be the result of oxygen picked up by the alloys from the thoria crucibles. However, crucible reactions are not necessarily an unmixed evil — remarkable improvements in the oxidation resistance of high-purity titanium resulted simply from melting this metal in a thoria crucible, without any intentional alloying. As received, this high-purity titanium gained 165 mg. per sq.cm. during 64 hr. in air at 1650° F., but the remelted metal gained only 7.3 mg. per sq.cm. We attribute this increased oxidation resistance to thorium dissolved by the titanium while it was being melted in the thoria crucible. The extent and effects of both oxygen and thorium pickup are being investigated further.

Most of our alloys were melted from magnesium-reduced titanium produced by the Bureau of Mines. However, a few alloys that were made from sodium-reduced titanium obtained from Titanium Alloy Mfg. Div. had better properties at high temperature. Here again, we are inclined to attribute the difference to small proportions of impurities, because the sodium-reduced titanium contained 1.3% silicon, 0.18% vanadium, 0.3% iron, 0.17% carbon and 0.05% copper.

Table I — Creep-Rupture Data for Various Temperatures and Loads

Composition		Stress, Psi.	Creep Rate Per Hr.	Rupture Time, Hr.	Rupture Strain, %
Ti*	Alloying Elements, %				
	Test Temperature, 1750° F.				
TA	25 Cr, 8.6 W, 16.4 Mo	15,000	0.420	0.8	34.1
B	25 Cr, 10.3 W, 19.7 Mo	15,000	0.167	0.7	16.7
TA	50 Cr, 8.6 W, 16.4 Mo	25,000	0.002	34	12.9
TA	50 Cr, 8.6 W, 16.4 Mo	15,000	0.0011	8.75†	1.6†
TA	50 Cr, 8.6 W, 16.4 Mo	15,000	—	0.01	—
TA	37.5 Cr, 8.6 W, 16.4 Mo	25,000	0.065	0.6	6.2
TA	31.6 Cr, 7.95 W, 16.75 Mo	25,000	0.130	1.0	27.4
TA	31.6 Cr, 7.95 W, 16.75 Mo	15,000	0.0095	6.0	17.4
TA	31.6 Cr, 7.95 W, 16.75 Mo	15,000	0.00555	12.8†	27.6
TA	31.6 Cr, 7.95 W, 16.75 Mo	10,000	0.002	24.5	9.1
B	31.6 Cr, 7.95 W, 16.75 Mo	25,000	0.580	0.35	20.1
TA	45 Cr, 8.6 W, 16.4 Mo	15,000	0.0005	80	5.1
Stellite 31‡		25,000	0.106	1	15
Stellite 31‡		15,000	0.003	25	12
	Test Temperature, 1650° F.				
B	9 Cr, 1 Th	24,000	10.0	0.03	55.6
B	5 Cr, 1 Th	12,000	0.014	19.3	54.9
	Test Temperature, 1600° F.				
BM	30 Cr, 20 Co	25,000	0.300	0.13	4.25
	Test Temperature, 1500° F.				
TA	—	5,000	0.0092	5.5	38.0
BM	27.5 Cr, 6 W, 11.5 Mo	25,000	0.640	0.87	55.4
BM	30 Cr, 15 Mo	25,000	0.470	0.67	31.7
BM	30 Cr, 10 Mo, 10 Ta	25,000	0.560	0.8	45

*Remainder titanium, from sources indicated as follows: BM, Bureau of Mines magnesium-reduced powder; B, Bar stock from Bureau of Mines; TA, Titanium Alloy Mfg. Div. sodium-reduced titanium. †Internal defect. ‡Values estimated by M. J. Manjoine from the available test data.

Note: The nominal compositions given in both Tables I and II represent percentages of the elements in the original furnace charge — not analytical determinations on the castings.

Table II — Results of Tensile Tests at Constant Strain Rate

Composition		0.2% Yield Stress, Psi.	True Stress at Ultimate, Psi.†	Strain at Ultimate Stress, %	Rupture Strain, %
Ti*	Alloying Elements, %				
	Test Temperature, 1750° F.				
TA	—	~4,000	3,900	~0.2	~60
B	—	—	2,600	—	36.4
BM	20 Cr, 10 W	—	4,490	—	98
BM	20 Cr, 10 W	5,080	6,040	0.9	64.9
BM	30 Cr, 10 W	6,500	7,150	0.5	83.2
BM	30 Cr, 15 W	7,500	8,200	1.1	49.0
BM	35 Cr, 15 W	6,120	9,350	3.12	25.6
BM	30 Cr, 6.6 W, 3.4 Mo	8,220	9,700	1.7	47.0
BM	37.5 Cr, 12.5 W	16,000	17,600	1.4	64.0
BM	27.5 Cr, 6 W, 11.5 Mo	10,100	10,200	0.55	59.4
BM	25 Cr, 8.6 W, 16.4 Mo	17,300	17,600	0.51	45.0
TA	25 Cr, 8.6 W, 16.4 Mo	20,750	21,600	0.7	29.3
B	24.5 Cr, 16.1 W, 8.4 Mo‡	13,700	14,980	1.2	75.6
B	24.5 Cr, 8.4 W, 16.1 Mo‡	8,140	14,700	1.1	13.2
B	24.5 Cr, 8.4 W, 16.1 Mo‡	9,890	13,700	0.66	18.1
BM	27.5 Cr, 17.5 W	7,060	8,500	1.5	14.7
TA	37.5 Cr, 8.6 W, 16.4 Mo	—	18,000	0	0
TA	45 Cr, 8.6 W, 16.4 Mo	—	26,500	0	0
TA	45 Cr, 8.6 W, 16.4 Mo	—	21,000	0	0
B	16.8 Cr, 11.9 W, 24.7 Mo	—	13,000	0	0
BM	25 Cr, 5 Mo	4,390	7,000	6.4	66.8
BM	25 Cr, 5 Mo	4,030	6,900	4.9	50.4
BM	25 Cr, 5 Mo, 5 Ni	3,300	6,110	1.9	43.6
BM	25 Cr, 5 Mo, 5 Ni	4,970	5,100	0.3	28.8
BM	30 Cr, 10 Mo	5,130	7,900	2.2	31
BM	30 Cr, 10 Mo	5,600	7,900	2.4	67.7
BM	40 Cr, 10 Mo	10,000	11,400	1.7	44.2
BM	40 Cr, 10 Mo	7,500	12,600	1.17	17.7
B	40 Cr, 10 Mo	12,970	16,300	1.6	26.9
BM	30 Cr, 15 Mo	10,420	13,500	1.9	18.3
BM	35 Cr, 15 Mo	11,530	13,800	1.3	49.2
B	27.5 Cr, 17.5 Mo	11,630	13,300	1.8	50.5
BM	30 Cr, 10 Zr	3,350	7,330	3.8	23.5
BM	30 Cr, 40 Zr	8,100	9,500	1.1	14.7
BM	30 Cr, 50 Zr	—	10,800	0	0
BM	20 Cr, 10 Ta	4,300	4,500	2.0	73.2
BM	30 Cr, 10 Ta	5,500	6,300	0.9	45.3
BM	30 Cr, 10 Ta, 10 Mo	11,120	12,100	0.8	44.0
BM	40 Cr	4,200	4,800	0.9	41.6
BM	40 Cr	5,400	6,190	0.8	21.5
BM	20 Cr, 10 Cb	3,800	4,500	2.3	67
BM	30 Cr, 10 Co	—	2,900	—	48
BM	30 Cr, 10 Co	2,900	5,850	—	11.5
BM	30 Cr, 10 Fe	5,100	5,520	2.2	82.5
BM	30 Cr, 5 Ni	2,580	3,250	3.7	24.8
BM	30 Cr, 5 Ni	—	3,850	0.1	26.2
BM	30 Cr, 5 V	5,050	5,320	0.8	54.5
BM	30 Ta, 10 Mo	7,580	7,620	0.4	94.8
BM	30 Ta, 10 W	5,800	6,000	0.7	84.5
Mild Steel†		1,500	2,500	—	—
Commercial Copper†		500	1,000	—	—
18-8 Stainless Steel†		3,800	7,500	—	—
Commercial Molybdenum† (annealed at 2600° F.)		17,000	20,000	—	—
Stellite 31†		21,500	27,000	2.4	11.6
	Test Temperature, 1600° F.				
BM	20 Cr, 10 W	7,550	10,500	1.3	30.9
BM	20 Cr, 10 W	7,500	8,500	0.5	124
BM	30 Cr, 10 W	9,700	11,100	1.0	59.7
BM	30 Cr, 15 W	11,250	15,000	1.8	29.0
BM	30 Cr, 15 W	10,020	13,300	2.0	25.7
BM	35 Cr, 15 W	15,440	18,900	2.0	49.3
BM	27.5 Cr, 6 W, 11.5 Mo	18,300	19,000	0.6	76.8
BM	27.5 Cr, 17.5 W	12,170	13,500	1.0	21.0
BM	25 Cr, 5 Mo	7,640	10,100	2.9	83.4
BM	25 Cr, 5 Mo, 5 Ni	7,010	7,820	2.3	35.3
BM	30 Cr, 15 Mo	13,900	17,500	0.9	15.4
BM	35 Cr, 15 Mo	15,400	23,400	2.5	33.0
BM	30 Cr, 10 Zr	4,930	5,750	4.8	50.3
BM	30 Cr, 30 Zr‖	11,100	13,500	1.6	12.6
BM	30 Cr, 30 Zr	10,800	12,500	1.4	13.4
BM	30 Cr, 40 Zr	14,300	16,800	1.0	6.7
BM	30 Cr, 50 Zr	—	18,200	0	0
BM	20 Cr, 10 Ta	5,700	6,300	0.7	89.6
BM	30 Cr, 10 Ta	8,610	10,000	1.8	41
BM	30 Cr, 10 Ta, 10 Mo	16,650	19,000	1.2	38.0
BM	30 Cr, 10 Fe	8,520	9,300	0.9	46.0
BM	30 Ta, 10 Mo	8,950	9,300	0.5	61.2
	Test Temperature, 1500° F.				
TA	—	10,100	10,000	0.67	70.3
BM	20 Cr, 10 W	11,150	11,000	1.1	57.3
BM	20 Cr, 10 W	11,800	13,000	1.2	98.3
BM	30 Cr, 10 W	13,050	15,600	1.3	31.2
BM	30 Cr, 15 W	20,900	24,000	1.5	27.4
BM	27.5 Cr, 17.5 W	17,000	22,500	1.6	53.7
BM	30 Cr, 30 Zr	14,500	16,700	1.0	11.0
BM	30 Cr, 40 Zr	15,400	17,000	0.24	0.24
BM	30 Cr, 10 Ta	12,700	15,200	2.3	35.7
BM	30 Cr, 5 Ni	5,570	6,690	1.5	34.2
	Test Temperature, 1400° F.				
BM	30 Cr, 30 Zr	19,400	21,800	1.0	4.7
BM	30 Cr, 40 Zr	—	16,800	0	0
BM	30 Cr, 60 Zr	Specimen disintegrated because of oxidation.			
BM	20 Cr, 10 Ta	10,200	11,000	1.0	81.4
BM	30 Cr, 10 Ta	18,940	20,100	2.4	—

*See first footnote to Table I. †For a strain rate of 0.5 per hr. ‡Plus 2% beryllium. §Values estimated by M. J. Manjoine from the available test data. ‖Test temperature, 1650° F.

CONSTITUTION OF SINTERED & WORKED TITANIUM-NICKEL ALLOYS

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THE TITANIUM-NICKEL system is being investigated by the Bureau of Mines in order to determine the range of composition in which useful alloys may occur. Our major interest is in the physical and mechanical properties of the alloys; however, lack of information about the titanium end of the phase diagram has made it desirable to study also the constitution of titanium-nickel alloys.

The alloys were prepared from powders, either by conventional methods of pressing and sintering or by the sheath rolling method described in last month's *Metal Progress*, p. 191. To accelerate the approach toward equilibrium, all alloys were worked at the temperature level under investigation and then returned to the furnace to permit diffusion to take place. Finally, the specimens were quenched to room temperature and examined metallographically. The identity of constituents was checked by X-ray diffraction, and supplementary data were obtained by thermal analysis and hardness testing.

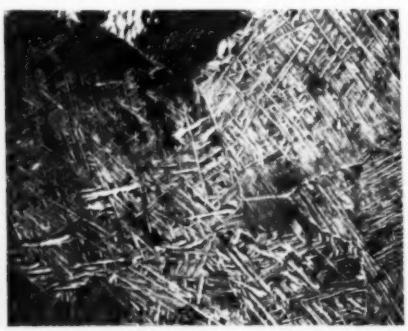
Early in the investigation, it was found that the specimens were not behaving as simple binary alloys. We attribute this to oxygen, believed present to the extent of 0.1 to 0.2% in the magnesium-reduced titanium powder. Other work currently under way on the titanium-oxygen system confirms this presumption, as do the data on several titanium-nickel alloys to which varying amounts of oxygen have been added. Accordingly, the phase diagram at the top of the opposite page should probably be considered a vertical section through the titanium-nickel-oxygen system at the oxygen level of the titanium powder.

Conspicuous features of this diagram are: *(a)* The large effect of nickel on the solidus line, which indicates that high-temperature alloys in this system must contain less than 12% nickel; *(b)* the ability of the body-centered cubic beta form of titanium to dissolve a maximum of 12% nickel; *(c)* the low solubility (less than 0.5%) of nickel in the hexagonal alpha form of titanium; and *(d)* the formation of the body-centered cubic gamma phase (an intermetallic compound) at about 41% nickel.

Low-nickel alloys quenched from the beta region exhibit a martensitic structure formed by decomposition of the beta phase. Typical examples of this structure are shown in Fig. 1 and 2. At higher nickel contents (5% and above) the beta phase is more stable and can be preserved by quenching, as indicated in Fig. 3, for a 9.45% nickel alloy.

0.52% Ni, Quenched From 900° C.
Untransformed Alpha + Martensitic Alpha

1.7% Ni, Quenched From 950° C.
Martensitic Alpha



9.45% Ni, Quenched From 950° C.
Retained Beta

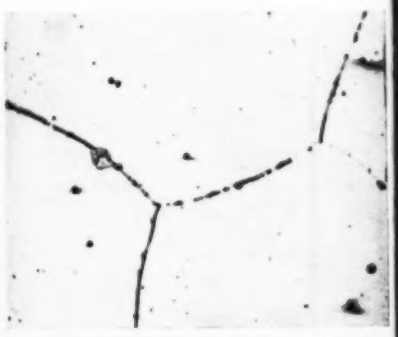
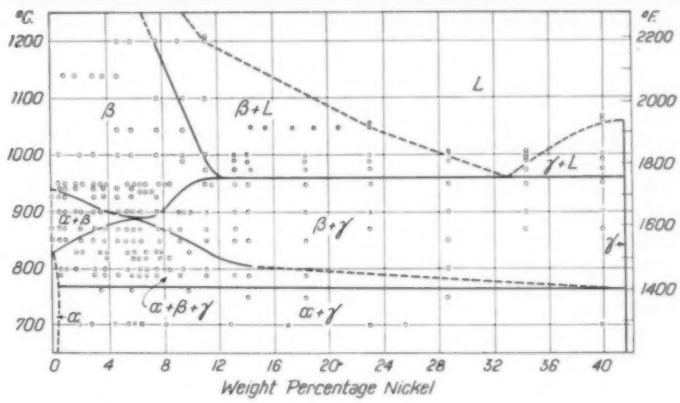


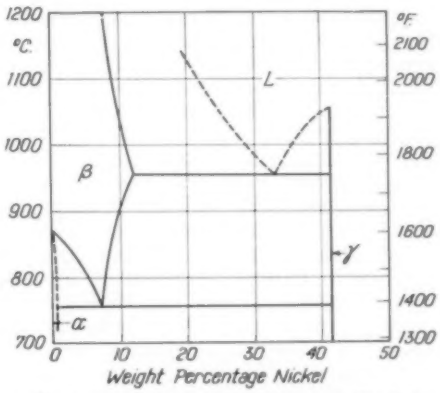
Fig. 1 to 3 — Titanium-Nickel Alloys Quenched From Temperatures at Which Beta Is Stable. 250 ×

It is expected that the greatest response to heat treatment will be obtained in the titanium-nickel alloys containing from 5 to 12% nickel, although structural alteration — and hence controlled variation in properties — is still possible in the alloys of lower nickel content. In the high-nickel range of composition, quenched specimens have shown a Rockwell hardness between C-45 and C-50, compared with Rockwell C-30 and C-40 for alloys containing from 2 to 4% nickel. Subsequent tempering at 750° C. (1380° F.) decreases the hardness to between Rockwell C-20 and C-25, producing alpha-gamma microstructures, as shown in Fig. 4 and 5. These resemble the alpha-Fe_3C structures obtained in steels tempered at high subcritical temperatures. One type of structure obtained on quenching from the three-phase region is shown in Fig. 6.

Our data permit some conjecture of the binary titanium-nickel system, and a tentative diagram is presented at the right. This shows only the titanium-rich portion of the system investigated in our laboratories and does not correlate directly with the nickel-rich portion of this system as given in the Metals Handbook. Since the nickel-rich alloys were made with impure titanium and by melting procedures, the results cannot be extrapolated from one diagram to the other.

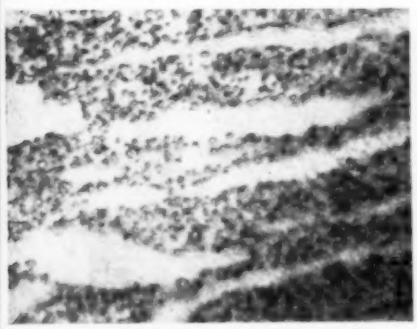
Vertical Section Through the Titanium-Nickel-Oxygen Diagram



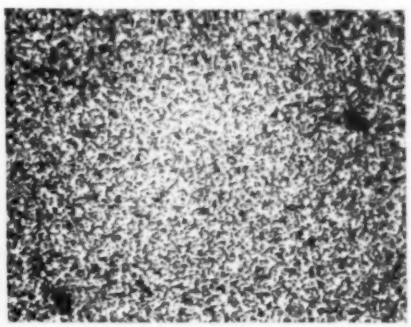


Tentative Diagram for Titanium-Nickel

4.7% Ni, Quenched From 750° C.
Alpha + Gamma



8.15% Ni, Quenched From 700° C.
Alpha + Gamma



6.35% Ni, Quenched From 800° C.
Alpha + Beta + Gamma

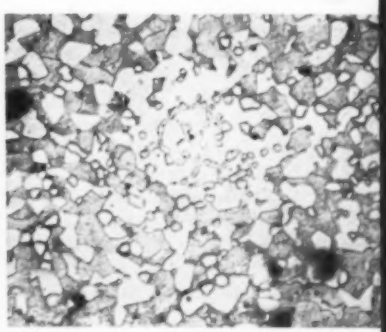


Fig. 4 to 6 — Titanium-Nickel Alloys Quenched From Below the Beta Range. Fig. 4, 500 ×; Fig. 5 and 6, 250 ×

PROPERTIES OF MELTED & FORGED TITANIUM-CHROMIUM ALLOYS

By D. J. McPherson and M. G. Fontana
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ALTHOUGH the technology of titanium has advanced rapidly during the last three years, the metal still has much the same position as would pure iron or pure aluminum if no steels or aluminum alloys existed. Serviceable titanium alloys must be developed for specific applications before the new metal can find large-scale engineering use.

The proportional limit of titanium is about three times that of fully cold worked austenitic stainless steel and, in some environments, the corrosion resistance is similar to that of 18-8. Titanium has also a desirable combination of high strength, low density and low vapor pressure. Chromium is notable for imparting oxidation resistance to alloys at high temperature. Titanium and chromium together may form a series of strong, corrosion resistant alloys, and these would be considerably lighter than ferrous alloys. It was with this background that, in March 1947, we began a study of titanium-chromium alloys under sponsorship of Wright-Patterson Air Force Base.

Induction-Melted Alloys — Our first small ingots (Fig. 1) were made in an induction furnace, either in a vacuum or an atmosphere of purified helium. Raw materials for this work consisted of 99% electrolytic chromium from various manufacturers and ductile magnesium-reduced titanium produced by the Federal Bureau of Mines.

The problems involved in melting titanium are very obtrusive indeed. Most of the difficulties in melting and casting were discussed in last month's *Metal Progress*, p. 195 to 200. In our work, the best crucible materials have been specially prepared, low-porosity beryllia and thoria, and we have obtained sound ingots, free from metallic contamination, by melting and rapidly solidifying the titanium alloys in crucibles made of these oxides. Vacuum-fusion analysis of one vacuum-melted alloy indicated gas contents of 0.002% oxygen, 0.001% nitrogen and 0.0014% hydrogen by weight. (The figure for oxygen is questionable because of uncertainties in the analytical procedure.)

Most of the induction-melted alloys were hard (about Rockwell C-40) and so brittle that they broke up during forging. Exceptions were the ingots prepared in low-porosity beryllia and thoria crucibles; these averaged about Rockwell C-25 and were readily forgeable at 1900° F.

Arc-Melted Alloys — To circumvent the crucible problem and to produce larger quantities of the alloys for more varied testing, it was decided to try arc melting. Three arc-melted titanium-chromium alloys weighing about 1 lb. each have been prepared at Battelle Memorial Institute. (The arc furnaces used were described in last month's *Metal Progress*, p. 197.) The resulting alloys were forged readily between 1700 and 1900° F., into ½-in. square bars, about 15 in. long.

The chemical quality of arc-melted alloys was better than 99.5%. The major impurity was tungsten, which increases with gassier charges, because of splashing of the melt onto the tungsten electrode and alloying at that point. The density of each of the alloys was less than 5 g. per cu.cm., compared with 4.5 for high-purity titanium and 7.1 for chromium.

Hardness of the as-forged alloys was about Rockwell C-40. The annealed material was not much softer. Water quenching from 2200° F. gave a hardness of about Rockwell C-49. This was the greatest hardness obtained in heat treated alloys prepared by arc melting.

The strength of this type of alloy was indicated by several tensile tests at room temperature. The 11% chromium

Fig. 1 — Induction-Melted 50-G. Ingots of Titanium Alloy Containing 13% Chromium

alloy had a tensile strength of 149,500 psi. in the stress-relieved condition, giving a strength-weight ratio of 31,150. (The strength-weight ratios of the strongest aluminum alloy, the strongest magnesium alloy, and steel of tensile strength 225,000 psi. are all about 29,000.) Limited stock precluded the testing of duplicate bars of each composition, and forging defects in the test specimens made it impossible to obtain the maximum strength of which the alloys were capable. No reduction of area or elongation was observed.

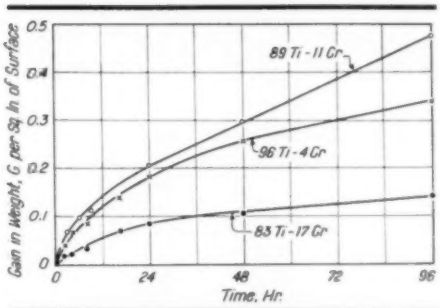

Fig. 2 — Scaling Characteristics of Titanium-Chromium Alloys in Still Air at 1600° F.

The 11% chromium alloy shows excellent resistance to 65% boiling nitric acid and to both warm and boiling saline solutions, but the alloy corrodes rapidly in sulphuric acid solutions.

The scaling characteristics of the alloys were studied in still air at 1600° F. A double layer of scale forms; the inner (probably chromic oxide) is green and quite dense and adherent; the outer (probably titanium oxides and nitride) ranges in color from yellow-brown through blue-violet to black, and flakes off during cooling. The alloy having the highest chromium content (17%) formed a denser outer scale, having by far the least tendency to flake off. Also, the oxidation rate of this alloy was much lower than those of the other alloys, as indicated in Fig. 2.

The as-forged structure consists of broken-up polyhedral grains (Fig. 3). Annealing this alloy at 2000° F. causes grain growth and heavy precipitation of an unidentified second phase (Fig. 4). After being water quenched from 2200° F. the alloy shows much less precipitate (Fig. 5). No breaks in the heating or cooling curves were observed during thermal analysis of the three alloys between room temperature and 1800° F. Failure of the tests to show a thermal effect corresponding to the precipitation observed microscopically is probably the result of lack of sensitivity in the instrument, which was designed for measuring the transformation temperatures of steels, or sluggishness of the precipitation reaction in the titanium-chromium alloy.

The work described is still in progress. An improved induction melting unit has been built and an arc furnace adapted to both vacuum and inert-gas melting is nearing completion. DuPont sponge titanium will be used as well as the Bureau of Mines material in future work, and other grades of chromium, lower in oxygen content, will be tried. Arc melting will be utilized for preparing ingots weighing from 1 to 3 lb., of various compositions, for further evaluation. At the same time, some induction melting experiments will be continued, principally as a means of evaluating crucible materials.

As Forged | Furnace Cooled From 2000° F. | Water Quenched From 2200° F.

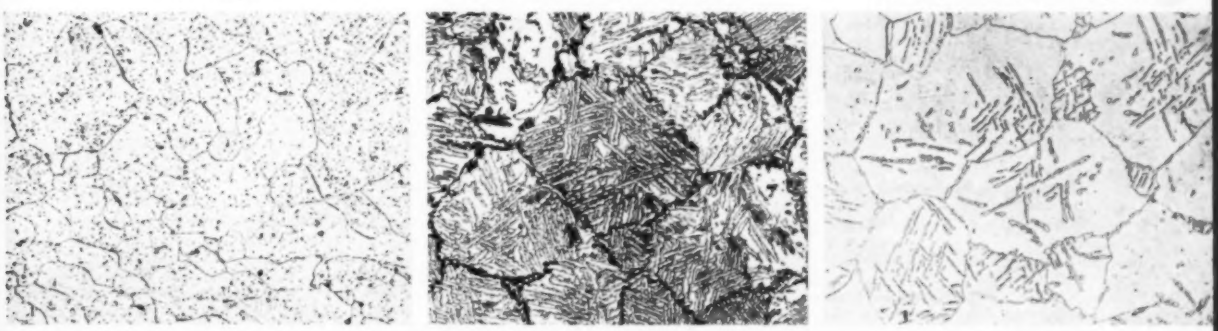

Fig. 3 to 5 — Microstructures of Arc-Melted Titanium-Chromium Alloys Containing 17% Chromium. 100 ×

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By Charles S. DuMont
Battelle Memorial Institute
Columbus, Ohio

THE REFERENCES given here have been selected chiefly from the bibliography listed as the second item below; most of the publications appearing before 1925 have been omitted. About 20 references more recent than 1946 (and hence not given in the bibliography mentioned) have been included here. Articles with data on both production and properties are listed under Production.

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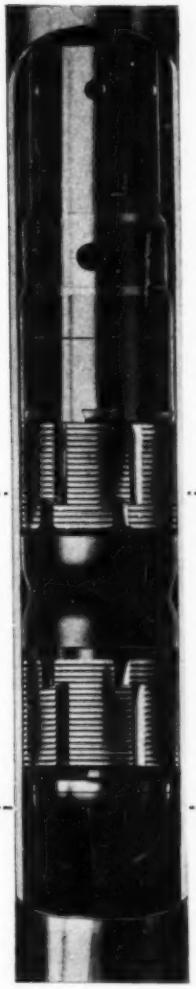
(Continued on p. 398)



Drillable Bridging Plug made by the Lane-Wells Company, Los Angeles, California, whose successful setting depends on the shear strength of two small pins of Revere Herculoy. These plugs vary from 38" to 58" in length.

These are the two small pins, made of Revere Herculoy to standard shear strengths, thus assuring proper setting of the Tripset plug. Pins are shown actual size.

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Proper setting of this plug within the well depends on those two small pins. They must shear at exactly the right load, imposed by a special setting tool. If the pins should shear too easily, the plug might not be securely set in the well and might fall to the bottom; if the pins were too tough, the plug might not set at all. From the material standpoint, successful operation of a device costing as much as $310.00 depends on the uniform shear strength of a few cents' worth of rod.

It was to assure that uniformity that the Revere Technical Advisory Service was called into action. Studies were made of the needs, tolerances specified, and means devised to assure meeting them. The specifications when finally drawn up were rather unusual, and their fulfillment is another demonstration of Revere's ability to turn out special orders when absolutely necessary. Incidentally, Lane-Wells Company, maker of the Drillable Bridging Plug, also uses Revere phosphor bronze, strip brass, Herculoy rod and free-cutting brass rod for other parts.

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PERSONALS

Harold K. Work, currently president of the American Society for Metals, has been appointed research director of the engineering college of New York University. Dr. Work was previously director of research for Jones and Laughlin Steel Corp.

J. E. Layton has recently been appointed general manager of the refrigeration division of International Harvester Co.

S. G. Blowers, formerly with the Easy Washing Machine Corp., has been placed in charge of the Syracuse, N. Y., office of MacInnes Steel Sales Co.

Merrill Brothers of Maspeth, N. Y., announce the appointment of **Howard L. Franks** as director of sales. He has been sales manager of the Charles Fischer Spring Co. and a sales executive of Carpenter Steel Co.

W. S. Newton has retired from the U. S. Navy and is now associated with the Metallurgical Research and Development Co. of Washington, D. C.

Arthur D. Little, Inc., announces the election of **Bruce S. Old** to the board of directors. Dr. Old is in charge of process metallurgy for the company and is also consultant to the Office of Naval Research and the Atomic Energy Commission.

A. Oram Fulton has been elected chairman of the board of directors and executive officer of Wheelock, Lovejoy & Company, Inc. He will continue as treasurer. **Frederick H. Lovejoy**, who has been executive vice-president of the company, has been elected president to succeed Mr. Fulton in that office.

Devon W. Fryback has been appointed district manager of the Albany, N. Y., office of Minneapolis-Honeywell Regulator Co. and its Brown Instruments division. Mr. Fryback, who has been with the company for 21 years, has been industrial manager at Hartford, Conn., most recently.

The International Nickel Co., Inc., announces that **John F. Thompson**, executive vice-president since 1936, has been elected president. **Robert C. Stanley**, formerly chairman of the board and president, continues as chairman. **Paul D. Merica**, former vice-president, is now executive vice-president.

After receiving his master's degree from Michigan State College, **Robert A. Campbell** entered the employ of the Dow Chemical Co., Midland, Mich., as a research metallurgist in the magnesium research laboratories.

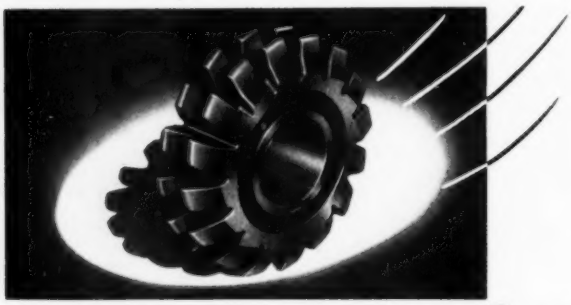
C. J. Gaspar is now sales manager of the De Bothezat Fans Div., American Machine & Metals, Inc., East Moline, Ill.

Joe R. Gilbert has joined American Welding and Mfg. Co. of Warren, Ohio, as a metallurgical engineer.

Olof G. Lorentzson is at present superintendent of Buck Brothers, Inc., Millburg, Mass.

Allegheny Ludlum Steel Corp. announces that **C. A. Scharschu**, formerly director of research, has been appointed assistant technical director, and **L. C. Hicks**, formerly associate director of research, has become director of research.

Harold J. Elmendorf has been promoted by American Steel & Wire Co. from division metallurgist to chief spring engineer of the Worcester, Mass., south works. He has been with American Steel & Wire since 1938.

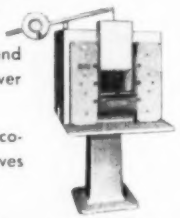


Reduce Tooling Costs Increase Production

WITH SENTRY HARDENING

Full hardness and maximum toughness result when your high speed steel tools are hardened in Sentry Electric Furnaces using Sentry Diamond Blocks. Unusual contours and sharp corners are faithfully retained.

With Sentry Diamond Blocks a neutral atmosphere is maintained — no oxidation, no scaling, no reduction in size. Tools may be thoroughly soaked for maximum hardness without danger of burning. High resistance to breakage and longer tool life result in higher production and lower tooling costs.



Sentry Model SY Electric Furnace

Sentry Furnaces are fast, clean and economical to operate. They pay for themselves within a short time.

Write for full information. Ask for recent bulletin 1054-A13

The Sentry Company

FOXBORO, MASS., U.S.A.

Sentry DIAMOND Block

Thank you Santa,—and you—and you—and you!

WE not only try to turn out "Top Quality Alloy", but we think we have done a pretty good job of turning out over a hundred "Top Quality Children" as evidenced by these scenes of our employees' children receiving their gifts from Santa.

Without the confidence of our many friends and customers, such scenes as these would not be possible. We, too, pause to say: "Thanks to you, and you, and you".

ALLOY CASTING COMPANY

Champaign, Illinois

ENGINEERING OFFICES IN PRINCIPAL CITIES

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Detroit: Frank W. Faery—Tel: Temple 1-7878
Pittsburgh: A. D. Sutherland—Tel: Atlantic 9366

MOST ADVANCED PRODUCERS OF HEAT AND CORROSION RESISTANT CASTINGS

PERSONALS

Timken Roller Bearing Co. announces that **William T. Strickland, Jr.**, sales engineer of the Steel and Tube Division, who was formerly stationed in Chicago, has been transferred to the Houston, Tex., sales office of the company.

N. S. Spence has recently been appointed director of research and development of Dominion Magnesium, Ltd., Haley, Ont.

Federated Metals division of American Smelting and Refining Co. announces that **H. L. Smith** has been appointed to the newly created position of executive technical engineer. Mr. Smith, who has been with the company for 25 years, has been a field metallurgist for the past ten.

John M. Connard is now metallurgist at Kiekhaefer Aeromarine Motors, Inc., Cedarburg, Wis.

Morse Hill is at Rensselaer Polytechnic Institute as a research fellow in the metallurgical engineering department.

McKee Centrifugal Blowers provide a reliable, economical source of pressure air for the combustion of gas and oil.

Due to a minimum of wearing parts, upkeep and service expense are negligible. Because current consumption drops promptly with reduction in air requirements, operating cost is low. Heavy, durable construction assures minimum vibration and long life

For air requirements from 2 oz. to 2 lbs., where steady air pressure is required at all times, McKee Blowers do an outstanding job. One blower will supply air to several furnaces or burners.

Write for Bulletins K-100 and K-110. Representatives in all principal cities.

Eclipse Fuel Engineering Company
ROCKFORD ILLINOIS
McKee Eclipse

Harold Buckholdt and **Gilbert Reed**, formerly metallurgical engineer and heat treat engineer of Allis-Chalmers Mfg. Co., have announced the formation of Reed-Buckholdt, Inc., a new heat treating plant located in Springfield, Ill.

James A. Bryson, formerly a metallurgist for Fansteel Metallurgical Corp., North Chicago, Ill., has joined the Chicago branch of the Office of Naval Research as scientific research administrator.

John R. M. Smith is now a student engineer with the National Tube Co. at McKeesport, Pa.

David N. Hoffman has assumed presidency of International Testing Labs, Inc., Newark, N. J., successor to Supreme Laboratory.

Following graduation from Carnegie Institute of Technology, **Phillip Roy Malenock** has accepted a position as junior metallurgist with National Tube Co. in Gary, Ind.

Irving S. Levinson, formerly in charge of metallurgical and corrosion work for the Bishop, Tex., plant of the Celanese Corp. of America, is now manager of process industries for Ampco Metal, Inc., Milwaukee.

After graduating from Missouri School of Mines, **Leonard F. Kane** has been employed as an industrial engineer at Columbia Steel Co., Torrance, Calif.

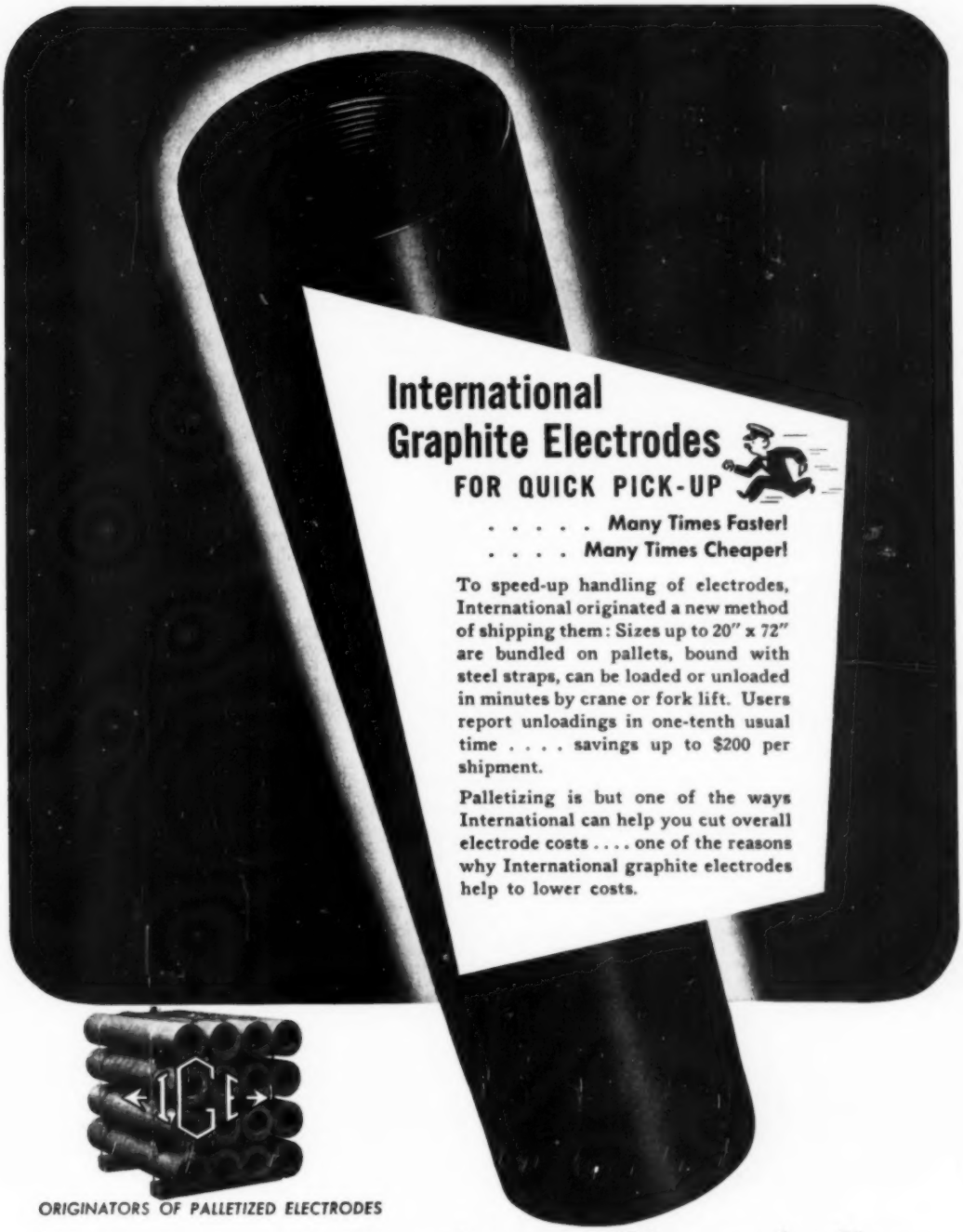
Bernhard Blumenthal, formerly research metallurgist with the American Platinum Works, Newark, N. J., has joined the staff of Argonne National Laboratory, Chicago, as associate metallurgist.

After receiving his B.S. in metallurgical engineering from the University of Illinois, **Leland F. House** has taken a position in the research laboratories of the Armco Steel Corp., Middletown, Ohio.

Theodore Gaynor is now employed as welding engineer for the Johnstown, Pa., plant of Bethlehem Steel Co.

Ronald F. Ball has joined the sales department of Lukens Steel Co., Coatesville, Pa., following graduation from Rensselaer Polytechnic Institute.

Miles K. Smith has been appointed vice-president and technical director of Jessop Steel Co., Washington, Pa. He was formerly with the Molybdenum Corp. of America and prior to that he was employed by Latrobe Electric Steel Co.


International
Graphite Electrodes
FOR QUICK PICK-UP
. . . . . Many Times Faster!
. . . . Many Times Cheaper!
To speed-up handling of electrodes, International originated a new method of shipping them: Sizes up to 20" x 72" are bundled on pallets, bound with steel straps, can be loaded or unloaded in minutes by crane or fork lift. Users report unloadings in one-tenth usual time . . . . savings up to $200 per shipment.
Palletizing is but one of the ways International can help you cut overall electrode costs . . . . one of the reasons why International graphite electrodes help to lower costs.
ORIGINATORS OF PALLETIZED ELECTRODES
International Graphite & Electrode Corp.
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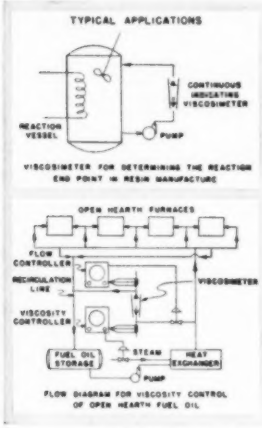
ST. MARYS, PA.

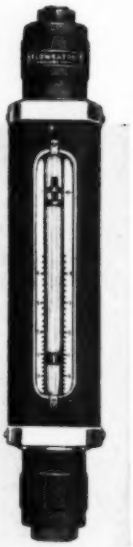
VISCOSITY MEASUREMENT

CONTINUOUSLY AUTOMATICALLY

(and with automatic control of the viscosity, if desired) RIGHT IN THE PIPE LINE, WITHOUT WITHDRAWAL OF FLUID SAMPLES, WITHOUT STOP-WATCH READINGS OF EFFLUX TIMES NOW AN ACCOMPLISHED FACT

Viscosimeters have graduated from the class of laboratory test instruments to full-fledged industrial instruments which perform their function without manipulation by an operator, just as temperature, pressure, flow and level instruments have been doing for many years.





PRINCIPLE OF OPERATION

Continuous viscosimetry has been accomplished by utilizing one of the unique properties of the F & P FLOWRATOR meter (formerly rotameter): ability to make metering floats either viscosity sensitive or viscosity immune. Into one FLOWRATOR are placed two metering floats, the one so shaped that it is very viscosity sensitive, the other one with the patented F & P viscosity immune shape. When fluid flows upward through the tapered metering tube both floats will, of course, rise in the normal manner. However, the elevation of the one float will be relatively slight, since it is produced solely as a function of fluid flow rate. The other float elevation will be much greater since it is a function both of viscous drag and flow rate. The space increment thus created between the two floats is a direct measure of viscosity. By selecting any particular flow rate which will give a convenient elevation of the one float to serve as a reference line, the other float elevation may be marked as viscosity graduations in terms of centipoises, centistokes, S.S.U. or any other desired units. Viscosity measurement all the way from .0008 to 800,000 centipoises is now possible.

Write for catalog 88 giving much additional information. F&P VISCORATOR continuous viscosimeters have been thoroughly tested in trial installations for well over a year.

FISCHER & PORTER CO.
DEPT. 9N-8Q HATBORO, PA.
FLOWRATOR
TRADEMARK

PERSONALS

Paul E. Lindberg, Jr., has resigned as melting superintendent at Copperweld Steel Co., Warren, Ohio, to accept a position as superintendent of melting with McLouth Steel Corp.

E. Jack Walker is now employed as laboratory investigator with the Bethlehem Steel Co., Bethlehem, Pa.

Joseph Soja, who was graduated from Missouri School of Mines recently, is assistant welding engineer with the Ladish Co., Milwaukee.

D. F. Rundle has been transferred from metallurgist of Centrifugal Fusing Co., Lansing, Mich., which is operated by Campbell, Wyant & Cannon Foundry Co., to assistant superintendent of Plant No. 6 of Campbell, Wyant & Cannon at Muskegon, Mich.

Wallace E. Smith is participating in the technical operating trainee program of the Republic Steel Corp., Buffalo, N. Y.

George E. Daschbach has been promoted by Jones & Laughlin Steel Corp. from steel works metallurgist to assistant general foreman of the Pittsburgh works blooming mills.

After graduating from Carnegie Institute of Technology, **Robert H. Stevenson** has been employed as a metallurgist in the laboratory of the Latrobe Electric Steel Co., at Latrobe, Pa.

G. D. Rahrer has been transferred from the Chicago office to the Pittsburgh office of Carnegie-Illinois Steel Corp., where he will be specification engineer in the metallurgical department.

George O. Nations, formerly Kansas City representative of National Tube Co., has been appointed manager of claims for that company and will be located at the main office in Pittsburgh.

Edward C. Prow, who was formerly with the Scripto Mfg. Co. in Atlanta, Ga., has accepted the position of supervisor of the machine shop at the Steel Heddle Mfg. Co., Greenville, S. C.

G. W. Paget has started a small foundry connected with the research laboratories of the de Havilland Aircraft Co., England, and is engaged in development work in the precision casting of turbine blades for the de Havilland jet engines.

SPEED CASE STEEL x1515

A LOW CARBON OPEN HEARTH PRODUCT

This shaft machined at 230 S.F.P.M.

It Increases PRODUCTION

It Improves QUALITY

It Lowers COSTS

It Simplifies CARBURIZING

Our Production expert will survey your plant to show you the possible increases in *Production*, improvement of *Quality* and reduction of your *Costs* by the use of SPEED CASE or SPEED TREAT steels.

Tear off here

ACTUAL PHOTOGRAPH

Speed Case Steel (.20 carbon) 1 inch cold drawn bar tied in a knot, cold, without fracture.

ATTACH TO YOUR LETTERHEAD AND MAIL TO EITHER COMPANY BELOW

Licensee for Eastern States

THE FITZSIMONS COMPANY

YOUNGSTOWN, OHIO

MANUFACTURERS OF A COMPLETE LINE OF COLD FINISHED CARBON AND ALLOY STEEL BARS

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HAMMOND · INDIANAPOLIS · CHICAGO

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STAINLESS STEEL RINGS

AN ECONOMICAL SPECIALTY of G. O. CARLSON INC.

- *All stainless steel analyses to chemical industry standards.*
- *Rough cut or rough machined from plate or forged and rough machined.*
- *Any size—any thickness—any quantity.*
- *Your orders and inquiries will be given prompt attention.*

G. O. CARLSON, INC.

Stainless Steels Exclusively
300 Marshalton Road, Thorndale, Pa.
PLATES • FORGINGS • BILLETS • BARS • SHEETS (No. 1 Finish)
Warehouse distributors in principal cities

PERSONALS

Paul Fine is now assistant director and head of the casting instruction department at the Jelenko School of Precision Casting, Inc., New York, N. Y.

Emanuel Gordon, formerly on the staff of Massachusetts Institute of Technology, is now chief metallurgist of Reeves Instrument Co., New York, N. Y.

Frederick James Brown has been transferred by Chance Vought Aircraft Division, Dallas, Tex., from quality control to foreman of final assembly department.

R. M. Garrison, a past chairman of the Texas Chapter A.S.M., has changed positions from the Verson Allsteel Press Co., Chicago, to the Federal Machine and Welder Co., Warren, Ohio.

Frederick W. Hassett, a recent graduate of the University of Pittsburgh, is employed as a process engineer at the Ellwood works, Ellwood City, Pa., of the National Tube Co.

J. A. Kyger, formerly at Oak Ridge National Laboratory, is now senior civilian in the nuclear power branch of the Bureau of Ships, U. S. Navy Dept., Washington, D. C.

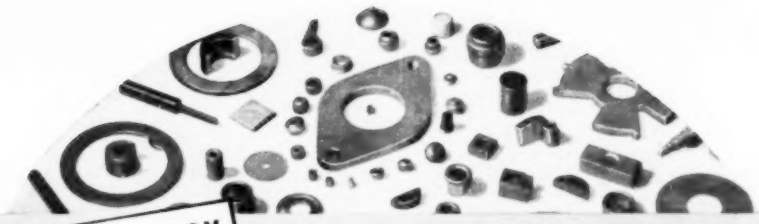
William C. Coons, formerly metallographer for the Kellex Corp. laboratory in Silver Spring, Md., has assumed a position at the experimental laboratory of the Climax Molybdenum Co., Detroit.

Kenneth B. Dempsey, formerly with the Crescent Research Laboratory, Crucible Steel Co. of America, has joined the research staff of the Heppenstall Co., Pittsburgh, Pa., as research metallographer.

V. Paul Treciokas is now a member of the metallurgical staff at the Winchester Repeating Arms Co., New Haven, Conn.

Formerly chief metallurgist in charge of the corrosion laboratory, **Frank S. Karger** is now in the operating section of the tank car division of General American Transportation Corp., East Chicago, Ind.

Karl Thomas Aszt, formerly of the United States Metals Refining Co., is now working for his Ph.D. at the University of Toronto under a scholarship awarded by the Research Council of Ontario. He is also on the staff of the department of metallurgy at the university.



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THE MACHINES UNIVERSALLY USED

POWDER METALLURGY is the process being chosen for the manufacture of many products because of the cost savings produced from this automatic, high speed production method. Parts such as porous, self-lubricating bearings, carbon brushes, and insulators, Alnico magnets, carbide tool bits, magnetic radio cores, contact buttons, gears, cams and literally thousands of other items are accurately and automatically made with unbelievable cost savings on Kux Presses.

BUILDERS of the most complete line of machines available for this industry, Kux Presses have been selected by all the leading manufacturers for the superiority in design and construction built into every model. A penny post card will bring you detailed information and an illustrated catalogue.

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Who said it costs more

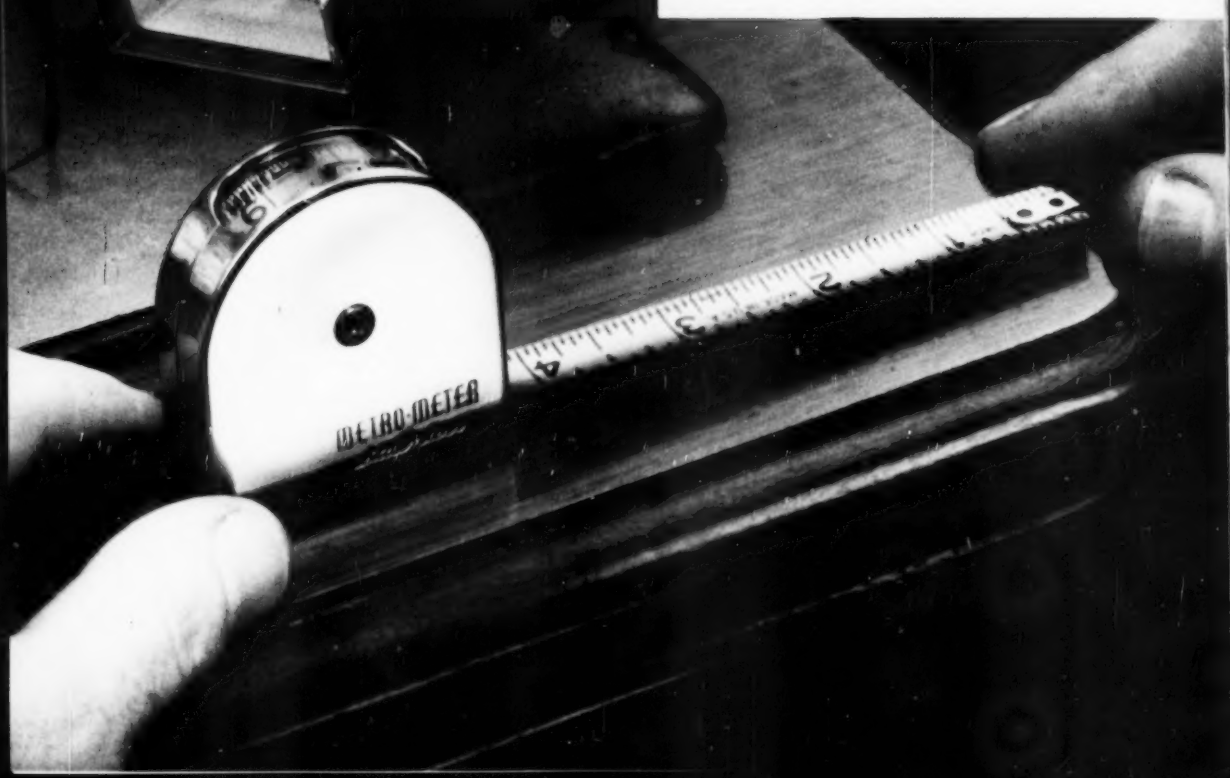
Here's where Stainless actually cuts cost 42.7%

COMPARISON AND

Cold Rolled Steel as against Stainless Steel

COLD ROLLED STEEL

Basic Cost of Tools. Experienced life of tools plus average cost of maintaining dies, pro-rated basis.	$.0152
Punch Press Operations	$.0180
Preparation for Chrome. Polish cold rolled before plating to remove "peel" and prepare finish to take clear color.	$.0224
Cost of Chrome Plating. including depreciation of equipment.	$.1331
Plating Scrap. Material scrapped because of prohibitive cost of stripping and re-chroming.	$.0140
Inspection	$.0060
Assembly line hold-ups. Costs over Time Study standard hour due to "built-up" pieces and chrome flashes interfering with assembly.	$.0230
Finished units rejected or returned due to chipped or peeled plating resulting in "seconds" on line.	$.0480
Cost of material .025" Stock less scrap value.	$.0121
Total	$.2918



to use Stainless Steel?

ANALYSIS OF COSTS

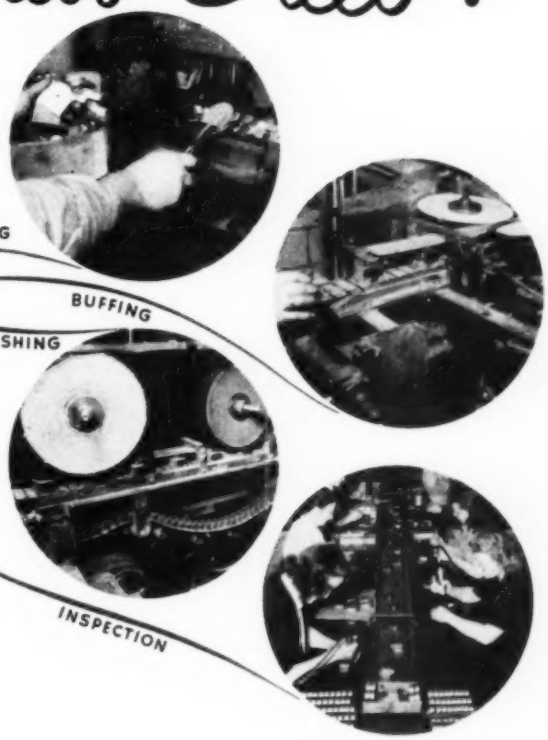
as experienced by Dart Mfg. Co., Mason, Mich.

STAINLESS STEEL

Basic Cost of Tools ..... Experienced life of tools plus average cost of maintaining dies, pro-rated basis.	$.0334
Punch Press Operations	$.0180
Polish and Buff ..... including depreciation of equipment and re-running of faulty buffing.	$.0512
Inspection	$.0060
Cost of Material .020" Stock ..... less scrap value.	$.0584
Total	$.1670

Cold Rolled Total Costs . . . . . *$.2918*
Stainless Total Costs . . . . . *.1670*
Actual Experienced Savings . . . . . *$.1248 per case*

Percentage Reduction in Cost 42.7%



THE "Metro-Meter" is a little device you'll soon be seeing a lot more of. It's a dial-reading steel rule with built-in scribe that men just naturally "take to" because it's practical, obviously useful, and, encased in Stainless Steel, is permanently good looking.

It's the case we want to talk to you about. Originally it was made of cold rolled carbon steel, chrome plated. The steel, itself, was inexpensive. But by the time it was prepared for plating, and plated—after the costs for rejections and returns due to over-plating, under-plating, chipping and peeling were added —each case cost a little over 29 cents.

By using lustrous satin-finish Stainless Steel in place of cold rolled carbon steel, however, all plating costs as well as rejections and returns were eliminated. Even though the initial cost of the Stainless Steel used was about five times that of the carbon steel formerly used, the final *finished* cost in Stainless was exactly 16.7 cents per case—a saving of almost 12½ cents each, which means a 42.7% reduction in cost.

What is more, with the magic word "Stainless" now stamped on the case, an almost irresistible plus has been added. Sales for the "Metro-Meter" which formerly had been good, immediately became considerably better. Thus, Stainless has done here what it has done for many other products — improved appearance, increased durability and reduced sales resistance. And in this instance, it has actually reduced costs as well. In short, a product made of Stainless Steel does *not* necessarily cost more—it only looks as though it did.

We would be glad to have the opportunity to show you where U·S·S Stainless Steel can be applied to improve YOUR product — to increase its desirability — and, more often than you may expect, to reduce its cost as well.

AMERICAN STEEL & WIRE COMPANY, GENERAL OFFICES: CLEVELAND, OHIO
CARNEGIE-ILLINOIS STEEL CORPORATION, PITTSBURGH & CHICAGO
COLUMBIA STEEL COMPANY, SAN FRANCISCO · NATIONAL TUBE COMPANY, PITTSBURGH
TENNESSEE COAL, IRON & RAILROAD COMPANY, BIRMINGHAM
UNITED STATES STEEL SUPPLY COMPANY, WAREHOUSE DISTRIBUTORS, COAST-TO-COAST
UNITED STATES STEEL EXPORT COMPANY, NEW YORK

United States Steel Corporation Subsidiaries
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☐ Please send me the new book, "An Introduction to U·S·S Stainless Steel."
☐ Please have a Stainless representative call on me.

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City..... Zone.... State.....

U·S·S STAINLESS STEEL

SHEETS · STRIP · PLATES · BARS · BILLETS
PIPE · TUBES · WIRE · SPECIAL SECTIONS

UNITED STATES STEEL

Every spring a picture of careful coordination...

You can't see it but it's there—the careful planning at Wallace Barnes that develops your blueprints into gleaming, vibrant springs. Real craftsmen mix the ingredients of metal, mechanics and motion in the right proportions to give true value in quality and endurance for your particular purpose.

Next time you have the picture of a spring in mind, let Wallace Barnes help to give it substance and reality.

Wallace Barnes SPRINGS

SMALL STAMPINGS • WIRE FORMS • HAIRSPRINGS • COLD ROLLED SPRING STEEL

WALLACE BARNES COMPANY
BRISTOL, CONN.

DIVISION OF THE ASSOCIATED SPRING CORP.
AND IN CANADA, THE WALLACE BARNES CO., LTD., HAMILTON, ONTARIO

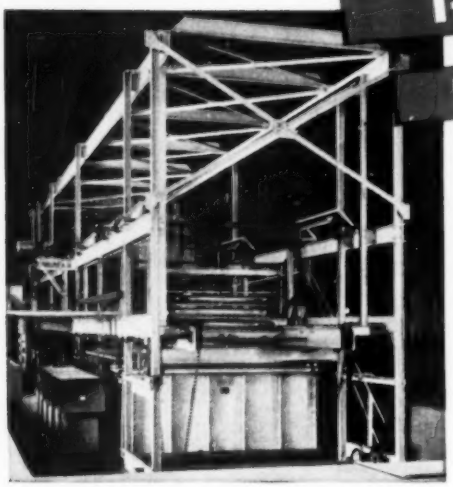
FINISH-MACHINE PARTS *before* YOU HEAT TREAT THEM!

It's entirely practical

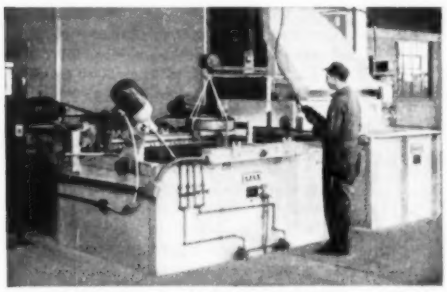
BY MARTEMPERING OR AUSTEMPERING IN AJAX SALT BATHS

It's a lot cheaper

It speeds production



Automobile bumpers are austempered in mass production in this Ajax mechanized unit. Fast salt bath heating cycle saved ⅔ floor space required by radiant heating unit.



Martempering bearing races (through-hardened to 57-61 RC.) in salt baths eliminated die quenching equipment and reduced distortion. Savings in final grinding operation alone quickly repaid investment.

Make a really worthwhile saving by eliminating expensive finishing on treated parts!

The development of the Ajax Isothermal Heat Treat Process for martempering, austempering and other interrupted quenching operations has replaced the conventional quench and temper method in hundreds of installations because of its ability to deliver uniformly heat treated parts remarkably free from distortion. The range of products being treated include dies, gears, tools, bearing races, crankshafts, blades, automobile bumpers, springs, revolver parts, cutlery, business machine parts, piston rings, cast iron cylinder sleeves, wrenches, agricultural implements, etc. Besides the benefits resulting from greatly reduced distortion, Ajax furnace users profit from the following additional advantages:

ELIMINATION OF QUENCH CRACKS
PREVENTION OF SCALING AND DECARB
INCREASED TOUGHNESS AND DUCTILITY
REDUCED FLOOR SPACE
FASTER HANDLING WITH LESS LABOR
ADAPTED TO MECHANIZATION

Write for Ajax Isothermal Bulletin 120. Better yet, let us treat a batch of your specimen parts under actual working conditions in the Ajax Metallurgical Service Laboratory. See for yourself the outstanding advantages of this method.

AJAX ELECTRIC COMPANY, INC.
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The World's Largest Manufacturer of Electric Heat Treating Furnaces Exclusively!

ASSOCIATED COMPANIES:
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AJAX ELECTROTHERMIC CORP. AJAX ENGINEERING CORP.

IN CANADA:
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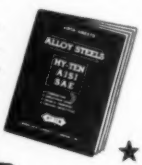
AJAX HULTGREN ELECTRIC SALT BATH FURNACES

OVER ONE HUNDRED YEARS OF CONTINUOUS SERVICE. ROUNDS, SQUARES, FLATS, HEXAGONS, OCTAGONS

BILLETS AND FORGINGS FOR PRODUCTION, TOOL ROOM AND MAINTENANCE REQUIREMENTS.

The selection of alloy steel grades necessarily varies with each manufacturer's needs and opinions. Some prefer HY-TEN alloy steel, while others recommend standard A. I. S. I. steel. However, differences in choice need not mean different sources of supply . . . just contact the Wheelock, Lovejoy warehouse nearest you. There you will find all grades of HY-TEN alloy steel as well as standard A. I. S. I. . . . grades to meet every need and opinion. By dealing with Wheelock, Lovejoy, you have the advantage of prompt delivery from a nearby source, plus courteous help from men who know metallurgy.

WL *steels are metallurgically constant. This guarantees uniformity of chemistry, grain size, hardenability—thus eliminating costly changes in heat treating specifications.*

Write today for your FREE COPY of the Wheelock, Lovejoy Data Book. It contains complete technical information on grades, applications, physical properties, tests, heat treating, etc.

PERSONALS

F. J. Palermo has been transferred by the J. I. Case Co. from the engineering department of the Racine, Wis., plant to superintendent of the new farm machinery factory at Anniston, Ala.

Alfons F. Uriwal, who has recently completed his metallurgical engineering course at Missouri School of Mines, is taking the sales engineer training course of the Aluminum Co. of America.

After receiving his M.S. from Pennsylvania State College, **John A. Bauscher** has accepted a position in the Pittsburgh research laboratory of the Carnegie-Illinois Steel Corp.

Clayton O. Matthews has recently joined Western Light Metals, Inc., Spokane, Wash., as metallurgist.

John S. Fisher has recently been elected president and director of the General Metals Powder Co., Akron, Ohio. He has been with the company since 1929.

Warren H. Richards is now industrial sales representative in the Boston, Mass., district for Shell Oil Co., Inc.

Edwin A. Glenn, Jr., formerly senior metallurgist in the research department of the Mack Mfg. Corp., has joined the New Holland Machine Co., New Holland, Pa., as metallurgist for development engineering.

Quaker Chemical Products Corp. announces the appointment of **W. J. Haring** as technical director. Mr. Haring joined Quaker in 1944 as plant supervisor and has been director of metals research since 1945.

General Electric Co. announces that **David Harker** will head its new crystallography division which will be located at the Knolls Laboratory. Dr. Harker joined G.E. in 1941 to do crystallographic work in the metallurgy division.

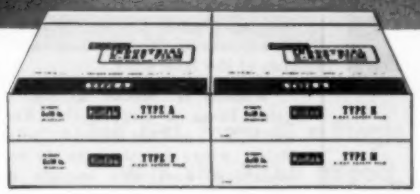
Gilbert J. Langenderfer has been appointed district industrial engineer in the Indiana territory for Surface Combustion Corp. He was previously in the Chicago office of the company.

H. C. Larson, assistant metallurgical engineer of Bethlehem Steel Co., has been appointed metallurgical engineer and secretary of plant committees dealing with the technical factors involved in steel plant operations.

WHAT'S THE RIGHT X-RAY FILM?

Product: Casting with 1/16-inch vane on 2-inch block
Material: High temperature alloy of cobalt, chromium, and molybdenum
Equipment: 1000-kv x-ray unit
250-kv x-ray unit

ANSWER:



A TYPE OF FILM FOR EVERY PROBLEM

To provide the recording medium best suited to any combination of radiographic factors, Kodak produces four types of industrial x-ray film.

Type M provides maximum radiographic sensitivity, high contrast, and exceptional detail under direct exposure or with lead-foil screens. It has extra fine grain and the speed is adequate for examination of light alloys at average kilovoltage and for much million-volt radiography of thin steel and heavy alloys.

Type A offers high contrast with about three times the speed of Type M, but with slightly more graininess. Used direct or with lead-foil screens for study of light alloys at low voltages, and of heavy steel parts at 1000 kv.

Type F provides the highest available speed and contrast when exposed with calcium tungstate intensifying screens. Has wide latitude with either x-rays or gamma rays, exposed directly or with lead screens.

Type K has medium contrast with high speed. For gamma-ray and x-ray work where highest possible speed is needed at available kilovoltage without use of intensifying screens.

KODAK INDUSTRIAL X-RAY FILM, TYPE M

In examining this casting, the radiographer used Type M Film because it provides maximum radiographic sensitivity. Its speed is adequate so that the million-volt unit got through the two-inch base block with reasonable exposure, while the 250-kv unit proved sufficient for the thin vane. The high contrast and detail-resolving ability of Type M revealed clearly the thread-like cavities present in the casting.

RADIOGRAPHY IN MODERN INDUSTRY

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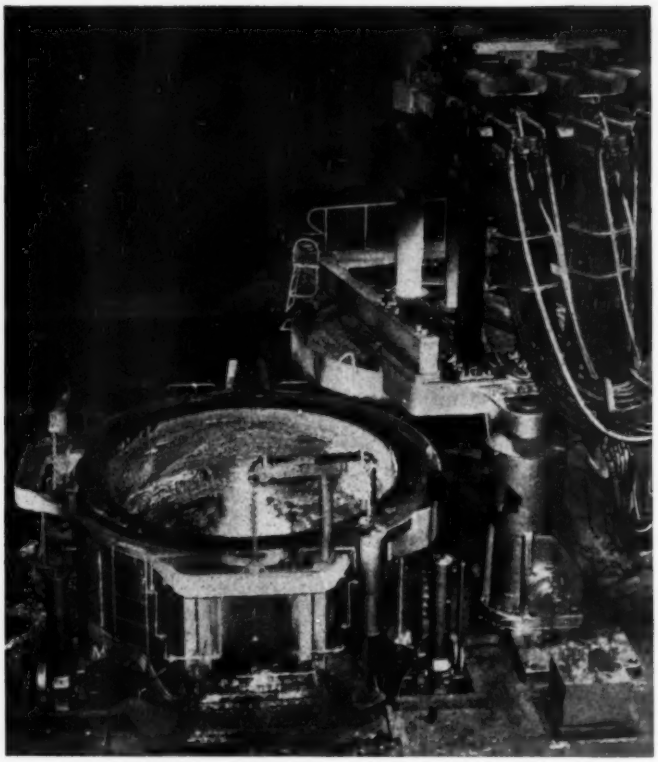

Take a good look at the shell of this size KT Moore Rapid Lectromelt Furnace. Here is one of the reasons for Lectromelt's vast superiority in the electric melting furnace field. The shell is built with proper proportion to permit operation with a comparatively shallow bath of large area—and provides a large slag-bath ratio for efficient refining. Then, too, the height of the side plates are sufficient to permit full furnace loading with one charge with many types of scrap. Two examples of many Lectromelt efficiencies.

Moore Rapid Lectromelt Furnaces are supplied in capacities ranging from 250 pounds to 100 tons. For full details, write today for the Lectromelt catalog.

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PERSONALS

F. R. Morral, formerly group leader of the metal trades laboratory of American Cyanamid Co., Stamford, Conn., has joined the department of materials engineering of the School of Applied Science of Syracuse University.

W. P. Saunders, formerly with the metallurgy division, National Bureau of Standards, is now research and development engineer of the Dow Chemical Co., Midland, Mich.

Peter A. Seward is now foreman in the heavy forge section of the aircraft gas turbine division, General Electric Co., West Lynn, Mass.

Leonard W. Kates, formerly a member of the staff of the division of industrial cooperation at Massachusetts Institute of Technology, has joined Sylvania Electric Products, Inc., Bayside, L. I., N. Y., as a development engineer.

John Ray Hopkins is now at the switchgear manufacturing plant of General Electric Co. in Philadelphia as engineer in the metallurgical section of the laboratory.

William G. McCue has left Volco Brass & Copper Co., Kenilworth, N. J., and has moved to Belfast, Maine, where he plans to do some consulting work and operate Bay View Farm.

Leslie G. Mustill is now with the Aluminum Co. of Canada at Shawinigan Falls, Canada.

The Eagle-Picher Co. announces that **A. Paul Thompson** has been appointed director of research and will work at the main research laboratory at Joplin, Mo. Dr. Thompson has been a senior fellow at Mellon Institute of Industrial Research since 1932.

B. H. Alexander, formerly on the metallurgy staff at Carnegie Institute of Technology, has joined the staff of the metallurgical research laboratories of Sylvania Electric Products, Inc.

Joseph Farley has been appointed sales manager of Wilhelm Engineering Co., Inc., Webster City, Iowa. He was previously with Reynolds Metals Co. and the Baldwin Locomotive Works.

Armco Steel Corp. announces the appointment of **Thomas L. Moore** as salesman with headquarters in Baltimore, Md.

VARIABLE WALL THICKNESSES

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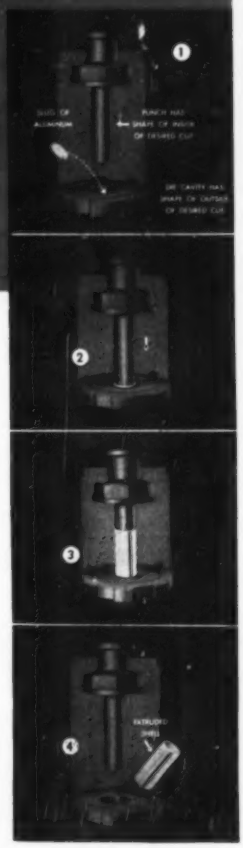

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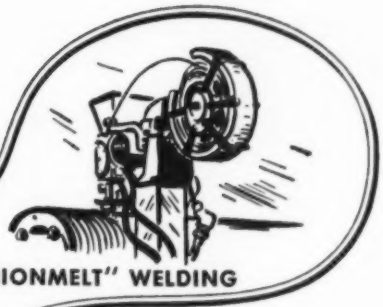
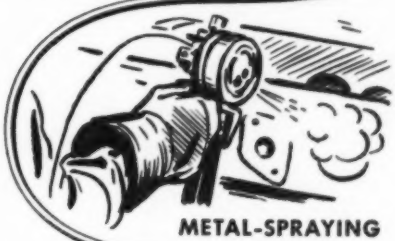
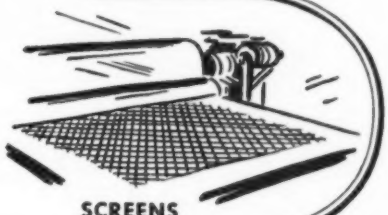


"UNIONMELT" WELDING



METAL-SPRAYING



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HASTELLOY nickel-base alloys, in the form of drawn wire, are available for the fabrication of corrosion-resistant screen, cloth, and baskets. The wire is also excellent for metal-spraying and for many types of automatic welding and hard-facing.

HASTELLOY alloys have a tensile strength comparable to that of the high-strength alloy steels, and possess unusual strength even at elevated temperatures. These alloys are specially designed to withstand the most severe conditions of chemical corrosion. Nickel-molybdenum alloy B is particularly resistant to hydrochloric and sulphuric acids, many organic acids, and all alkalies. Alloy C, a nickel-molybdenum-chromium-tungsten-iron composition, has excellent resistance to strong oxidizing agents, such as ferric chloride and wet chlorine, and is outstanding in its resistance to brine and salt spray.

In addition to HASTELLOY alloy wire, you can also obtain wire made of MULTIMET alloy—a cobalt-chromium-nickel composition developed for service at elevated temperatures.

Cut and straightened lengths or coils, in diameters down to 0.060 in., can be obtained directly from Haynes Stellite Company, Kokomo, Indiana. Wire in diameters less than 0.060 in. down to 0.002 in. is available from an associate company, Kemet Laboratories Company, Inc., Madison Avenue and West 117th Street, Cleveland 1, Ohio. For more complete information, write for a copy of the booklet, "HASTELLOY High-Strength, Nickel-Base, Corrosion-Resistant Alloys."

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Here's how this up-to-the-minute Westinghouse production tool is used:

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2. A blade is then automatically positioned in the heating coil.
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4. The blade is automatically dropped into the quenching bath at the moment for optimum hardening, and another blade is automatically positioned in the heating coil.

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March, 1949; Page 385

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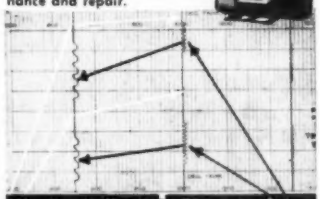

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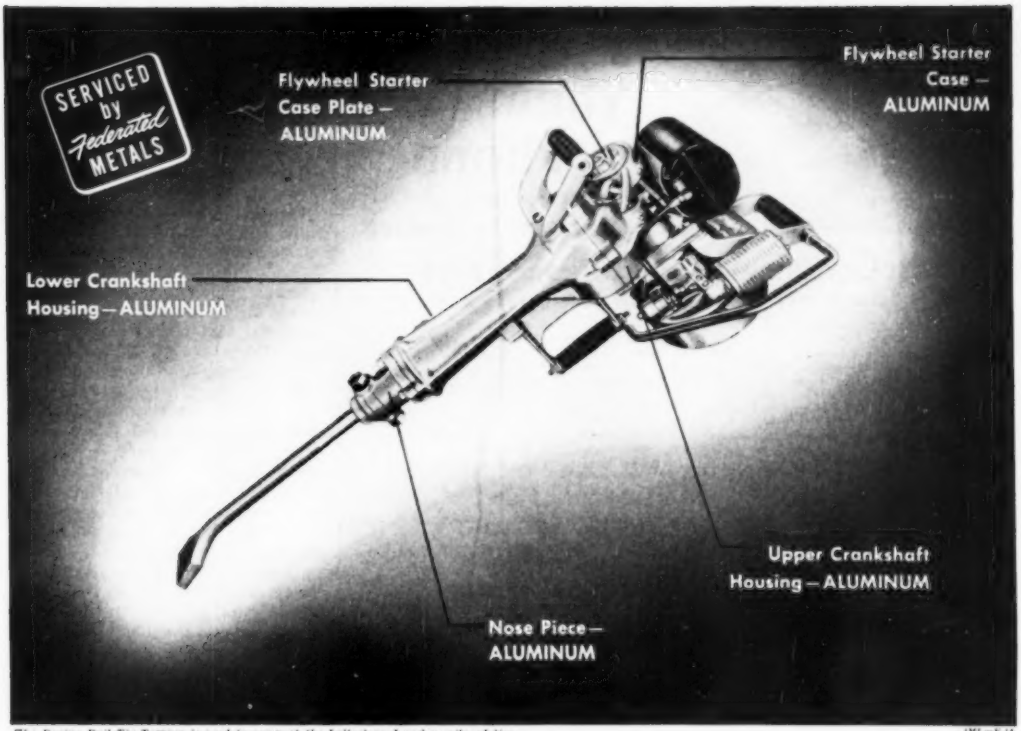
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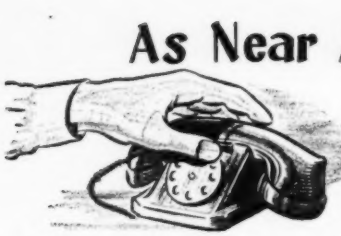

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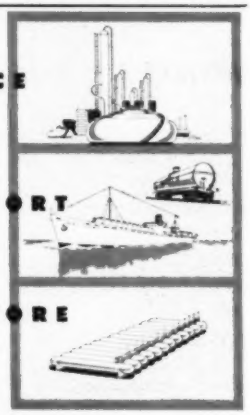

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OXIDATION OF Al*

THIS PAPER is a contribution to the study of the protective coat of oxide on aluminum. The author seems to have hoped to work out a practical method for increasing the thickness of that coat from the assumedly low figure of not more than 5 millimicrons (about 12 molecular layers) of an indefinitely hydrated oxide to 50 millimicrons of Al_2O_3 with the hardness of corundum.

Cabrera's own work consisted in the formation of a very thin layer of aluminum on a glass plate through the condensation of aluminum vapor, produced in a vacuum of 10^{-5} mm. of mercury. This layer, having a transparency of 15% for ordinary light and assumed to be ideally homogeneous and continuous, was then oxidized in dry and in wet air, in dry and wet ozone, with or without an ultraviolet irradiation. Temperatures were from room temperature to 300° C. The thickness of the layer of oxide formed was computed on the basis of the reflecting power and the transparency of the oxidized metal. Because the oxides are far more transparent than metallic aluminum, the increase in transparency was a good indication of progress of oxidation.

Although the tests lasted for many days, the curves of transparency versus time were still running steeply at the end, so that at no temperature could the process approach completion within an industrially permissible treating time. The computed maximum of the thickness of the layer of oxide was about 14 millimicrons — less than one third of the goal — and this was obtained only with a gas of 100% humidity.

The conclusion must be that the oxidation depends greatly on the temperature and humidity. Ozone does not increase the rate of oxidation to a technically useful extent, in comparison with air. Ultraviolet light does not affect the oxidation rate in the beginning, but nearly doubles the rate after one or two days.

It must be added that the strong effect of humidity on the rate of oxidation indicates that the coat formed must be a hydrated oxide. The hope of forming a coat of corundum can scarcely be realized.

*Abstracted from "Low-Temperature Oxidation of Aluminum", by N. Cabrera, *Revue de Métallurgie*, 1948, p. 86-93.

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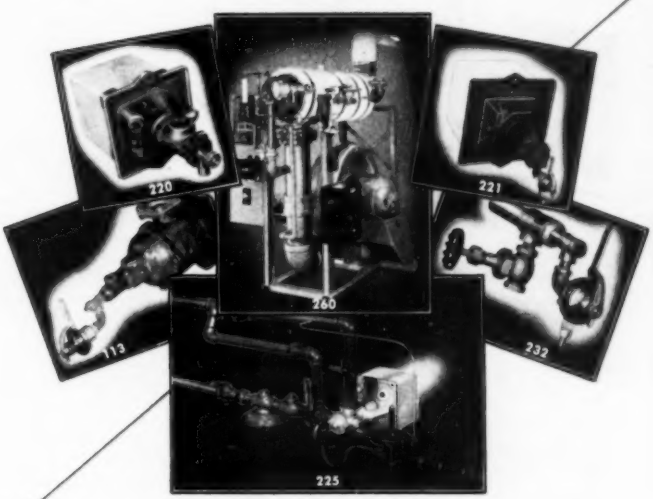

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*Dual-Fuel: The North American name for burners designed especially for both gas and oil. Fuel changed by merely turning valves.

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- ★ DIE SINKING
- ★ MANY OTHER TOOL-MAKING, FABRICATING, AND INSPECTION PROBLEMS

American Optical
COMPANY
Scientific Instrument Division
Buffalo 15, New York

Manufacturers of the SPENCER Scientific Instruments

INCLUSIONS

(Continued from p. 335)

more numerous silicate inclusions are formed. These inclusions largely disappear during a few minutes in the ladle, primarily by rising to the surface, partly by reduction and solution in the metal. By using a special type of ladle attached to the furnace and pouring through purified nitrogen, steel was obtained with silicate inclusions as low as 0.02×10^{-3}% by volume. During the discussion B. M. Larsen reported results obtained at U. S. Steel Corp.'s research laboratory similar to those of Hultgren's as to size and appearance of silicate inclusions in samples taken at various stages during the pouring operation.

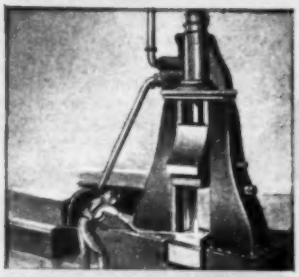
E. M. Cox, M. C. Bachelder, N. G. Nachtrieb, and A. S. Skapski (all of Institute for the Study of Metals, University of Chicago) found that the affinity of sulphur for copper is much stronger than that for iron and begins to exceed that for manganese at temperatures above 1350° C. (2460° F.). It appears that any metallic copper present in the scrap may be expected to pick up sulphur from the openhearth furnace gases and thus raise the sulphur content of the melt. (This paper was abstracted in *Metal Progress*, February 1949, p. 238.)

The role of thermochemical factors in basic openhearth production rate was studied by T. E. Brower and B. M. Larsen of the research laboratory, U. S. Steel Corp. It was shown that much of the variability in the time it takes to make a heat of basic steel is probably related to changes in net heat requirement. While changing the percentage of hot metal had little effect on the production rate, an increased amount of limestone or cold pig did slow it down. Substitution of light for heavy scrap will shorten the time, tap to tap, as will also a lower requirement of feed ore or of lower carbon at meltdown.

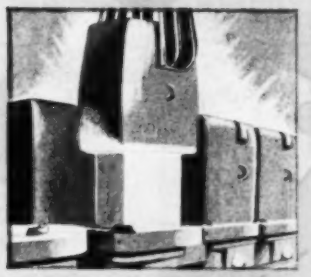
The paper by C. B. Post and G. V. Luerssen of Carpenter Steel Co. (see abstract in *Metal Progress*, Feb. 1949, p. 218) cast some new light on the origin of nonmetallic inclusions in steel. Their paper developed the concept that most of them had their genesis at the interface between the liquid steel and the ladle refractories. High manganese,

(Continued on p. 394)

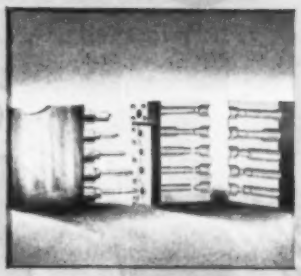
When the HEAT'S on...



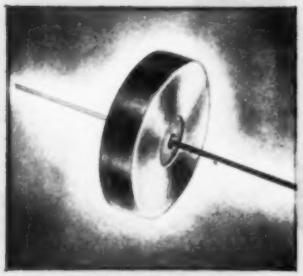
FORGING



STEEL INGOT STRIPPING

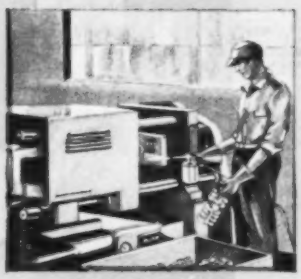


DEEP PIERCING



WIRE DRAWING

STRETCH FORMING



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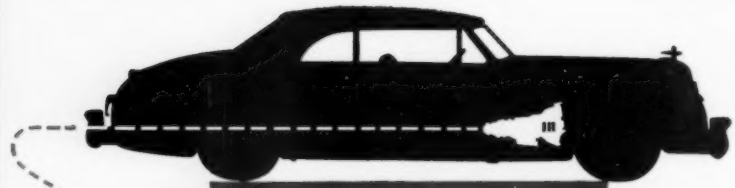
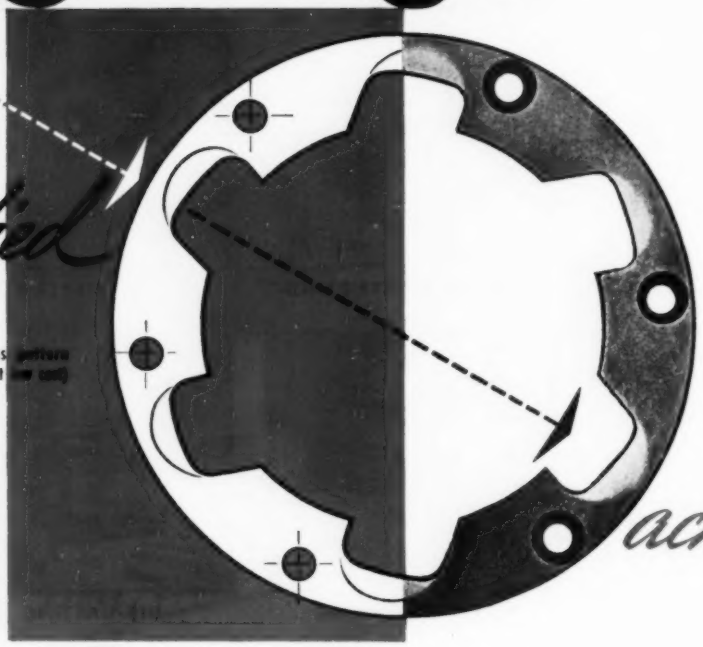


specified

Difficult hardness pattern on internal cam (at



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. . . with electronic temperature control. Rejects cut from 25% to nothing. Bottleneck broken, production trebled. Specified hardness values and patterns produced uniformly. 187 parts processed per hour.

That sums up Flamatic's remarkable performance in selective surface hardening internal lobes of the cams for a new automatic torque converter transmission. An engineered-to-the-job flame head with six ports heats the desired areas with high speed to within plus or minus 5°F of preset value – using exclusive Flamatic electronic temperature control. Operator simply loads parts, pushes button to start heating cycle, part is deposited in oil quench and then automatically delivered from quench on a conveyor.

Gears, cams, and similar parts up to 18" OD, and shafts up to 30" long have been successfully precision hardened on Flamatic. You can virtually **blueprint in advance** the hardness patterns and **duplicate the desired results in one part or many thousands.**

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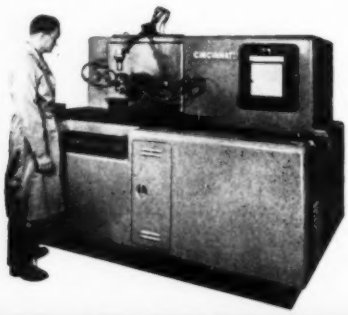

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

Use the prepaid postcard on this page to obtain the helpful literature described on these two pages.

146. Aluminum Handbook

A new, handy 24-page book contains a compilation of important aluminum industry specifications including ASTM, AMS, SAE, Federal, etc. Sent free on request for "Aluminum Alloys, U. S. Standard Specifications". *Federated Metals Div.*

147. Analyzer, Gas

Bulletin 701 describes a new portable analyzer that determines CO_2 instantly on a direct-reading meter in atmosphere heat-treating furnaces. Complete with aspirator bulb, dryer, hose and all accessories. *Charles Engelhard, Inc.*

148. Bars, Forging

There is a stainless steel "tailored" to fit your specifications for chemical and physical properties. Write for 112-page booklet of forging data "Evaluating the Forgeability of Steels". *Timken Roller Bearing Co.*

149. Bars, Steel

New booklet gives illustrated descriptions of Union-drawn steels used for carburizing and requirements which each serves. Also includes tables of shapes and sizes available. *Republic Steel Corp.*

150. Blast Cleaning

Five new bulletins will be sent on request to help you solve your cleaning problems. Write for "Barrels", "Tables" "Rooms", "Hydro-Sand Blast" or "Dust Control". *Pangborn Corp.*

151. Blowers

Bulletin 740, mailed on request, carries a complete description of the new Lindberg-Fisher blowers, including a chart of sizes and specifications for this outstanding heating unit. *Lindberg Engineering Co.*

152. Blowers

McKee centrifugal blowers provide a reliable, economical source of pressure air for the combustion of gas and oil. Bulletins K-100 and K-110. *Eclipse Fuel & Engineering Co.*

153. Carburizers, Gas

AGF gas carburizing equipment including the latest rotary gas carburizer, batch-type and vertical retort carburizers fully described in literature sent on request. *American Gas Furnace Co.*

154. Castings

20-page booklet "Misco Precision Castings" contains valuable technical information for manufacturers requiring small accurate alloy steel parts in quantity. *Michigan Steel Casting Co.*

155. Castings, Alloy Steel

Service qualities of vital parts increased by use of Pyrasteel, a modern specially developed furnace alloy that withstands oxidation and corrosion at temperatures up to 2000°F. Also resists gases and concentrated or diluted commercial acids. *Chicago Steel Foundry Co.*

156. Castings, Die

New revealing booklet "Hauling Costs Down", containing many facts about how fleet owners and truck body manufacturers have found Magnesium pays. *Dow Chemical Co.*

157. Castings, Die

Interesting new 8-page bulletin now available giving the complete story in colored illustrations of the multiple parts now available in aluminum bronze. Also includes a table of the physical properties of the Auromet alloys. *Aurora Metal Co.*

158. Castings, Precision

"New Horizons with Microcasting" a 10-page booklet containing complete information on precision investment casting technique, better methods of microcasting and illustrations of various parts manufactured. *Austenal Laboratories, Inc.*

159. Cold Heading

The new Waterbury-Farrel Hi-Pro solid die, double stroke crank header heads 150 blanks per minute from Ajax-Hogue drawn wire. Bulletin No. 111. *Ajax Mfg. Co.*

160. Contour Analyzer

An instrument designed to record small displacements, as in errors of contour in irregularly shaped sections. Movements as small as 10 microinches can be readily recorded and measured on the direct inking oscillograph. *Brush Development Co.*

161. Corrosion

"Corrosion by Concentration Cells" new booklet gives reasons for this condition as well as methods used to overcome it. Complete in every engineering detail and available on request. *International Nickel Co.*

162. Corrosion

For membership roster or any information regarding your particular corrosion problems. *American Hot Dip Galvanizers Assoc.*

163. Cutting Oils

Write today for the pamphlet "New Improved Gulf L-S. Cutting Base" which describes how production can be speeded up with lower costs and better finishes by using this newly developed cutting oil. *Gulf Oil Corp.*

164. Cutting Oils

For the right combination to suit your specific requirements, write for the Booklet "Cutting Fluids for Better Machining". *D. A. Stuart Oil Co.*

165. Die Casting Machines

The Prefill Injection System of die casting aluminum delivers a surge of pressure that increases the strength of the parts, and fills castings otherwise impossible to make with perfect uniformity. Send for free copy of the Lester Press. *Lester-Phoenix, Inc.*

166. Extrusions

"Alcoa Aluminum Impact Extrusions" is the title of a new booklet. Gives up-to-date information on short-cuts to designing of all types of parts by means of these new impact extrusion presses. *Aluminum Co. of America.*

167. Forgings

Literature describes forgings such as bucket wheels, discs, rotors, rings — or those of special analysis for gas turbine and jet propulsion application. *Midvale Co.*

168. Furnaces

An attractive two-color brochure describing the complete line of Loftus furnaces for every step along the way from open hearth to heat treating line will be sent on request. *Loftus Engineering Corp.*

169. Furnaces

Attractive 8-page folder has just been prepared describing the broad range of processes made possible with the complete line of Standard-Rated Industrial Furnaces. Bulletin So-141. *Surface Combustion Corp.*

170. Furnaces, Annealing

New vertical strip annealing furnaces improve silicon steel production and provide excellent surface characteristics which increase stamping die life. *Drever Co.*

171. Furnaces, Atmosphere

Fully descriptive literature sent on request. Outlines a controlled atmosphere furnace guaranteed to meet your heat treating requirements. *Delaware Tool Steel Corp.*

172. Furnaces, Brazing

Fully descriptive folder on furnace brazing, with many suggested "do's" and "don'ts". *Electric Furnace Co.*

173. Furnaces, Combustion Tube

For full information on combustion tube furnaces with exclusive feature of multiple heating units readily replaceable, write today for Bulletins HD-738, 138 and 1236. *Heat Duty Electric Co.*

174. Furnaces, Electric

Full information on fast, clean and economical furnace operation to obtain full hardness and maximum toughness in high speed steel tools described in bulletin 1054-A13. *Sentry Co.*

175. Furnaces, Melting

Full details on the Moore rapid lectromelt furnaces supplied in capacities ranging from 250 pounds to 100 tons, described in Lectromelt catalog. *Pittsburgh Lectromelt Furnace Corp.*

176. Grinders

New 6-page bulletin on AB Surfacers and grinders, including a description of new wet powder grinders and duo-belt wet surfacers, and illustrations of complete line of equipment for metallurgical laboratory. *Buehler Ltd.*

177. Grinding

48 pages of helpful information on grinding in foundries, steel mills, welding, forge and machine shops can be found in new booklet "Rough Grinding", just off the press. *Norton Company.*

178. Hardening, Surface

Flamatic with electronic temperature control cuts rejects up to 25%. Specified hardness values and patterns produced uniformly, at a rate of 187 parts per hour. Write for booklet of case histories. *Cincinnati Milling Machine Co.*

179. Hardness Tester

Leaflet describes the new Brinnell Hardness Reader. An instrument small enough to carry in your pocket provides a correct hardness reading with perfect accuracy. *Harry W. Dietert Co.*

180. Heat Loss Indicator

Bulletin 206 describes new Burrell CO_2 indicator for measuring excess air and per cent heat loss. All operating, installation and combustion engineers will want one of these new improved instruments. *Burrell Technical Supply Co.*

181. Heat Treating

Handy, vest-pocket data book has 72 pages of charts, tables, diagrams and factual data on late steel specifications, heat treatments, etc. *Sunbeam Industrial Furnace Div.*

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WHAT'S NEW

IN MANUFACTURERS' LITERATURE

182. Heating Elements

Non-metallic heating elements assure accurately controlled temperatures to provide uniform heat treatment. Informative literature is available. *Globar Div., Carborundum Co.*

183. Heating, Induction

Announcing a new comprehensive 48-page brochure on induction heating. First part devoted to general principles involved. Contents sectionalized so that all brazing applications are in one folder, all heating for forging applications in another and so forth. Write for all or any of these sections. *Ohio Crankshaft Co.*

184. Hydrofluoric Acid

"Hydrofluoric Acid Anhydrous" is the title of a new booklet containing one of the most complete compilations on the use of this chemical in condensing, fluorinating and alkylation processes. *Harshaw Chemical Co.*

185. Instruments, Temperature

New catalog giving the first complete listing of Speedomax Type G high-speed measuring instruments, including indicators, recorders and controllers. *Leeds & Northrup Co.*

186. Lubrication, High Temperature

Lubrication of equipment operating at high temperatures with "dag" colloidal graphite dispersions discussed in literature. *Acheson Colloids Corp.*

187. Metallographic Inspection

New 32-page catalog contains helpful information and listings of the latest equipment for preparing specimens. Write for Metallurgical Catalog 860. *Precision Scientific Co.*

188. Microscopes, Stereoscopic

Complete new line of 15 models in stereoscopic wide field microscopes described and fully illustrated in bulletin D-16, furnished on request. *Bausch & Lomb Optical Co.*

189. Molybdenum

Many suitable and economical compositions for applications of molybdenum are listed in convenient alphabetical order in the new booklet "Applications of Molybdenum Cast Irons", furnished on request. *Climax Molybdenum Co.*

190. Plating Generators

For electroplating, anodizing, electrocleaning or electropolishing in either large scale or small operations there's a Columbia M-G set available for you. Catalog MP-700 sent free on request. *Columbia Electric Mfg. Co.*

191. Polishing, Metallographic

For preparation of fine metallographic specimens a sturdy, smooth-operating table-model metallographic polisher is described in bulletin 90. *Eberbach & Son Co.*

192. Polishing and Buffing

The most economical way to change from slow, costly hand operation to automatic Packer-Matics is illustrated with actual time studies in bulletin 17. *Packer Machine Co.*

193. Potentiometers

Catalog 15-13 describes new instruments and systems using potentiometers, as well as many schematic diagrams, illustrative tables of various control forms, and other data helpful in proper instrumentation. Copy will be sent on request. *Brown Instrument Co.*

194. Presses, Powder

Powder metal production will save up to 75% through new developments of making in one piece parts which formerly required costly machining. *F. J. Stokes Machine Co.*

195. Presses, Powder

Powder metallurgy is being chosen for the manufacture of many products because of the economical high-speed production possible. Send for illustrated catalog showing the complete line of Kux presses available for every phase of this important industry. *Kux Machine Co.*

196. Pyrometers

An accurate way to measure extreme foundry temperatures is provided by the new simplified Pyro optical pyrometer. Light in weight — only 3 pounds — and available in 5 ranges from 1400° to 7500°F. Send for catalog 150. *Pyrometer Instrument Co.*

197. Pyrometers

For the finest results in proportional current-input control send for Bulletin PB1237, which describes the newest electronically operated pyrometer controller. *Bristol Co.*

198. Quenching

Send for catalogs now available on complete line of B & G pumps for correct oil quenching of heat-treated metals. *Bell & Gossett Co.*

199. Quenching

For full information on the newest developments of Ajax isothermal heat treat process in martempering, austempering and other interrupted quenching operations. Bulletin 120. *Ajax Electric Co.*

200. Silica Cement

A recently published, well-illustrated 6-page bulletin 507 gives complete description of the new Tayco-40 high-temperature cement, for bonding silica in the glass melting, openhearth and electric arc melting industries. *Chas. Taylor Sons Co.*

201. Spectrographic Equipment

Full description of the uses of this equipment for research in spectroscopy and spectrochemical analysis in metallurgy, chemistry and many other fields, given in catalog 1-4. *Jarrell-Ash Co.*

202. Steels, Alloy

New book now available on the selection of the proper alloy steel grades for each manufacturer's needs. Write for free copy of "Wheelock, Lovejoy Data Book. *Wheelock, Lovejoy & Co.*

203. Steels, Low Alloy

You can have one-third more production through the use of Hi-Steel which has nearly twice the working strength of ordinary steels plus the ability to stand up under impact loads. Send for free booklet giving full details. *Inland Steel Co.*

204. Steels, Stainless

For consistently fine stainless steels selected to resist nitric acid on the inside surface and atmospheric conditions on the outside, write for more detailed information on Vancoram Ferro Chromium steels. *Vanadium Corp. of America.*

205. Steels, Stainless

Valuable new 32-page book, "Allegheny-Ludlum Stainless Plates and Their Fabrication", now makes available all the data you need on sizes, types, and use of stainless plates, solid and clad. *Allegheny-Ludlum Steel Corp.*

206. Testing

For complete details on all the advantages of the new SR05 Reflectoscope for testing on billets and bars, ask for bulletin 3001. *Sperry Products, Inc.*

207. Testing

Literature gives detailed information on the Olsen "L" type hydraulic testing machine and others which provide a complete testing laboratory at the lowest possible cost. *Tinius Olsen Testing Machine Co.*

208. Testing, Fatigue

A whole new line of Baldwin testing machines including the Lazan Oscillator, the Rolling Load Fatigue Machine, and many others make accurate endurance tests possible on all kinds of materials. Informative, illustrated bulletins available on all types of testing machines. *Baldwin Locomotive Works.*

209. Testing Machines

Model KDR — Brinell testing machine for testing the hardness of metal parts is capable of checking up to 800 pieces per hour. *Steel City Testing Machines, Inc.*

210. Vacuum Pumps

The high volumetric efficiency of Kinney vacuum pumps is ideal for exhausting lamps or tubes, sintering metals, dehydrating oil or coating lenses. Bulletin V45 gives complete information. *Kinney Manufacturing Co.*

211. Viscosity Measurement

Viscosity measured continuously and automatically, if desired, in the pipe line without withdrawal of fluid samples. Write for catalog 88 describing this and many other uses of the Flowrator meter. *Fischer & Porter Co.*

212. Welding, Aluminum

With the new Aircomatic process, an entirely different fabricating technique, aluminum and weldable alloys can be joined in thicknesses from ⅛" to 2" in all positions — flat, horizontal, vertical or overhead. Send for complete information on this outstanding development. *Air Reduction Sales Co.*

213. Wire, Alloy

Hastelloy nickel-base alloys are available for fabricating corrosion-resistant screen, cloth, and baskets. Also for metal spraying and many types of automatic welding and hard-facing. Booklet "Hastelloy High-Strength Nickel-Base, Corrosion-Resistant Alloys" gives complete details. *Haynes Stellite Co.*

214. Wire Rope

New pocket-sized handbook available on request entitled "Wire Rope Is A Machine". Interesting illustrations give men on the job a simple explanation of how wire rope works, how it should be operated, and how to select and order wire rope construction for long service life. *Jones & Laughlin Steel Corp.*

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METAL PROGRESS

7301 Euclid Avenue, Cleveland 3, Ohio

March, 1949

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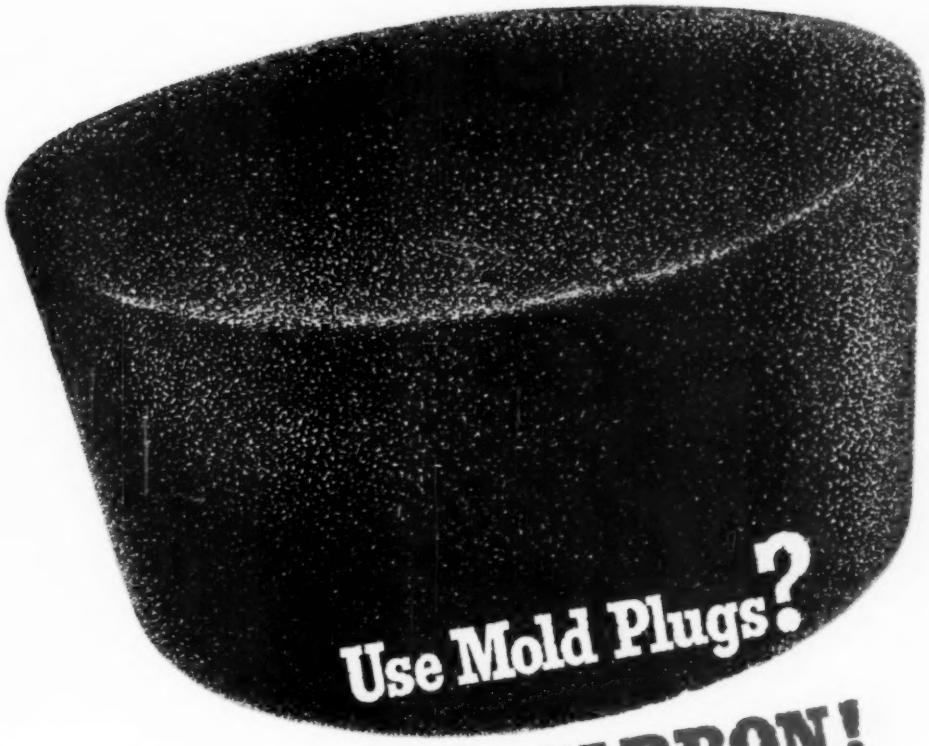

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1 With "National" carbon mold plugs, there is no contamination of ingot.

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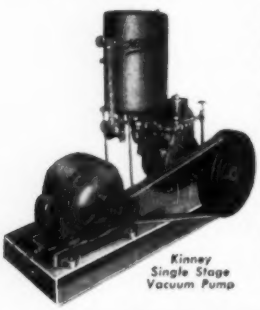
KINNEY

In this vacuum furnace, engineered and built by National Research Corporation, Cambridge, Mass., ultra-high quality brazing of large electronic tube components is accomplished in a vacuum of less than one micron — 1/760,000th normal atmospheric pressure! Kinney Vacuum Pumps, working with diffusion pumps, have made possible this outstanding achievement in Industry — brazing without oxidation under extremely low absolute pressures.



Kinney Single Stage Vacuum Pump

The high volumetric efficiency of Kinney Vacuum Pumps assures extremely fast pump down and very low absolute pressures. Kinney Vacuum Pumps are ideal for exhausting lamps or tubes, sintering metals, dehydrating oil or food products, and coating lenses. They are entirely dependable on all types of vacuum processing systems and require minimum attention and maintenance. Perhaps low pressure processing with Kinney High Vacuum Pumps can improve your product and reduce its production cost. Kinney Single Stage Vacuum Pumps test to low absolute pressures of 10 microns . . . Compound Pumps to 0.5 micron. Bulletin V45 gives complete information.

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SLAGS

(Starts on p. 332)

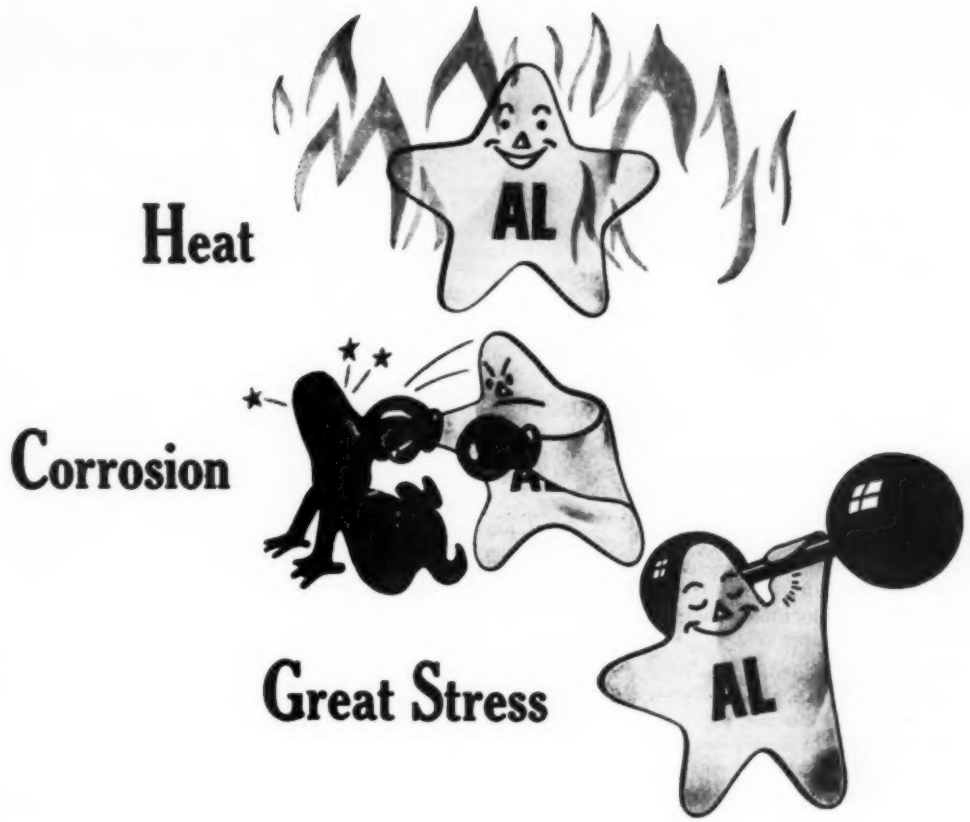
together with low silicon content, led to more inclusions than when manganese and silicon were substantially equal, and it was suggested that cleaner steels could be made if specifications permitted a better chemical balance.

C. E. Sims, H. A. Saller, and F. W. Boulger of Battelle Memorial Institute, examined the relative deoxidizing powers of some elements. In steelmaking, manganese, silicon, vanadium, and magnesium appeared to be weak deoxidizers, while titanium, zirconium and aluminum seemed to be strong ones. Calcium, thermodynamically, would appear to be a strong deoxidizer, but in practice it is weak.

In their paper on the ionic nature of metallurgical slags, John Chipman and L. Chang took a long step toward a more complete understanding of slag reactions. The report treats slag-metal and slag-gas reactions from a thermodynamic viewpoint, and is based upon the assumption of complete ionization in the slag. The theory was discussed and it was shown that the concept of ion activities may be useful even without definite knowledge of the degree of ionization within the slag at particular temperatures or compositions.

A new approach to one of the most important problems in the steel industry was outlined in a paper by S. F. Eaton, R. W. Hyde and B. S. Old of the Arthur D. Little organization, which traced the path of sulphur through the coke oven into the blast furnace. This has already been summarized in *Metal Progress* last June. Radioactive iron pyrite was prepared from sulphur 35, and mixed with a full-scale charge of coal going into a coke oven. The course of the pyritic sulphur was then traced to determine the quantity evolved in the gas, and the quantity remaining in the coke. Probably the most significant fact uncovered in the work is that pyritic and organic sulphur appear in the coke in proportion to their concentration in the coal. It would be concluded from this that at present there is no satisfactory way of reducing the sulphur content of coke by choosing coal of high or low pyritic or organic sulphur. The active discussion which followed the presentation indicated that metallurgists are

(Continued on p. 396)



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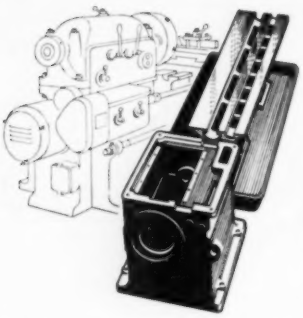

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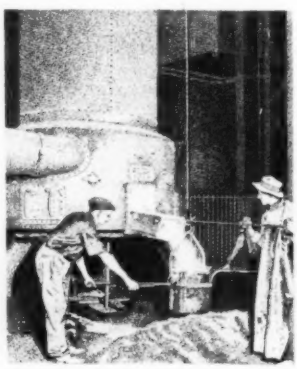
(Starts on p. 332)

alert to the value of tracer elements as a new research tool. Most of the work of this sort is in medical and biological laboratories; of the industrial researches only a half-dozen or so have been applied to problems in the production or use of metals. This marked disproportion is a curious fact; no reasonable explanation was forthcoming.

T. E. Brower and B. M. Larsen of the research laboratory, U. S. Steel Corp., compiled data from several blast furnaces to correlate the variables affecting sulphur elimination in the smelting of iron ore. The Al_2O_3 content of the slag has little effect on the transfer of the sulphur from the iron to the slag. Manganese in the iron appears to have a large effect on the sulphur content of the pig as well as on the desulphurization ratio; in fact, under certain conditions the manganese content of the iron may be the chief determining factor.

Sulphur equilibrium between liquid blast furnace slag and molten metal was also studied by G. G. Hatch of Armour Research Foundation, who made observations over a wide range of slag compositions at temperatures of 1425 and 1500° C. (2600 and 2730° F.). He used a special furnace with an atmosphere of carbon dioxide. He found that the sulphur in the metal was not directly proportional to the sulphur in the slag; the desulphurization ratio is controlled by the excess basicity, where excess basicity is defined as $(CaO + 2/3MgO) - (Al_2O_3 + SiO_2)$.



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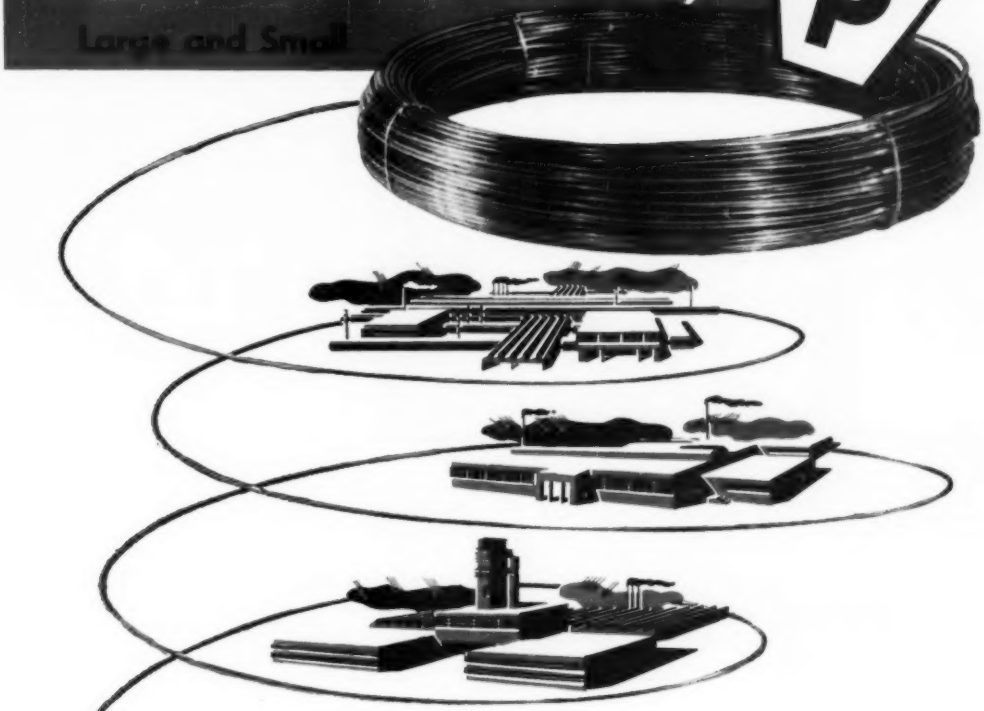

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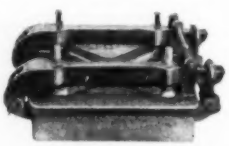

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(Continued on p. 400)

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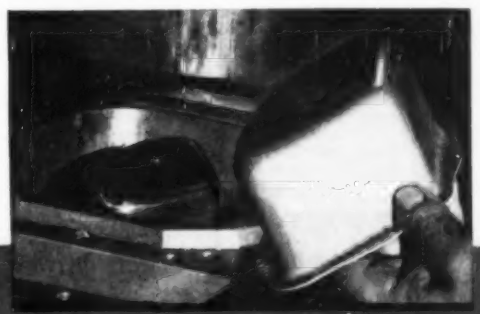

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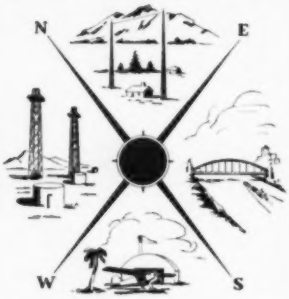

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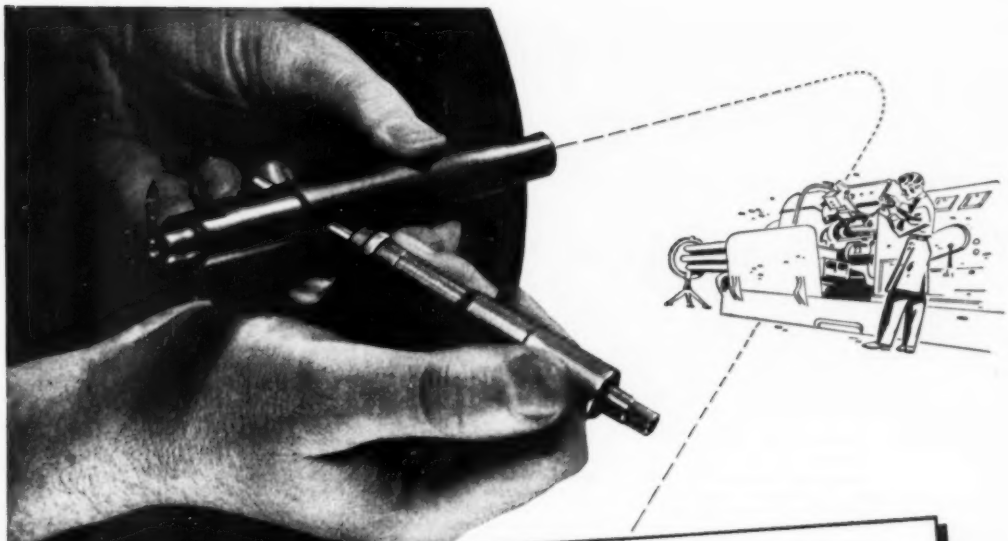

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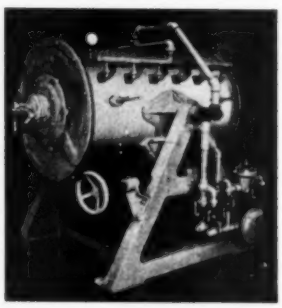

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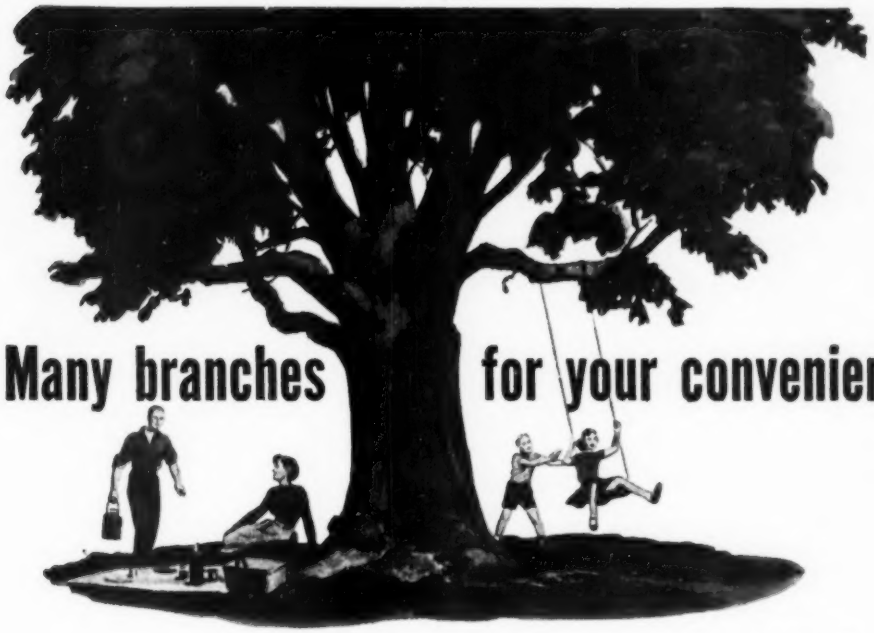

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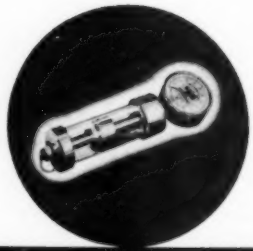

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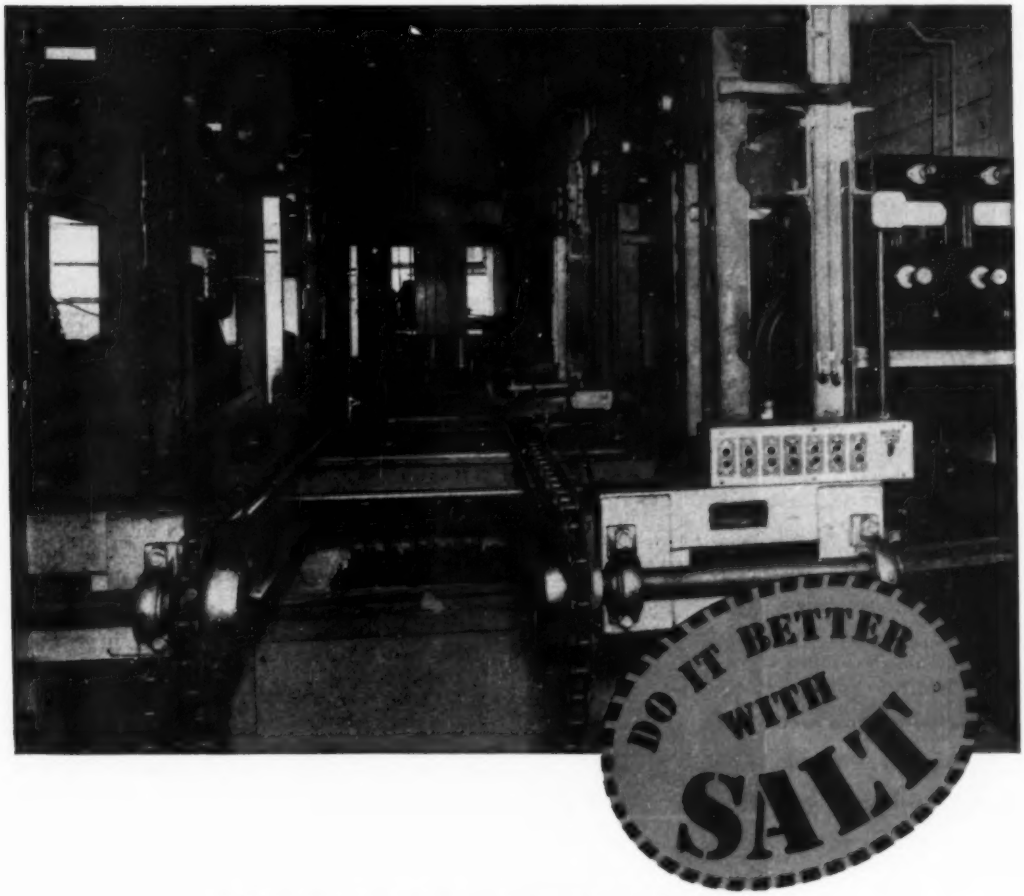

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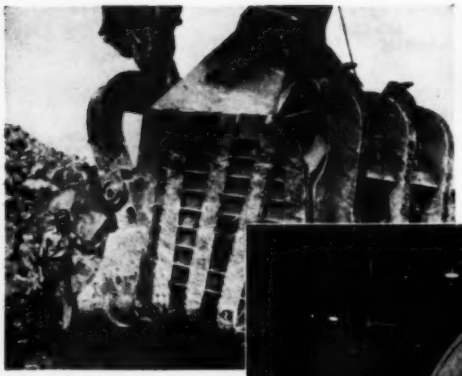

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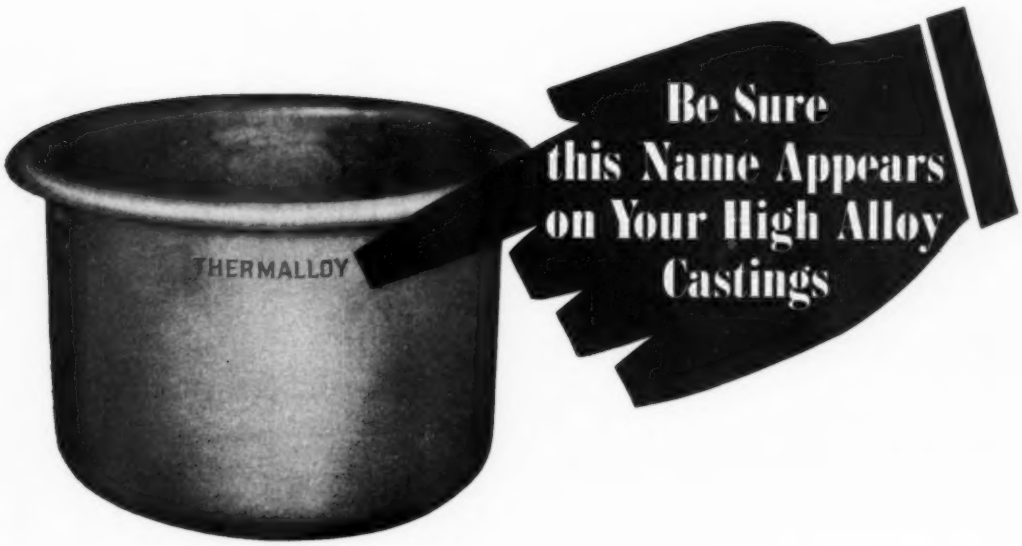

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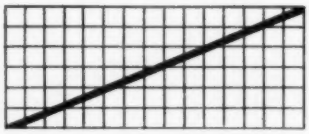

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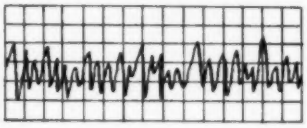

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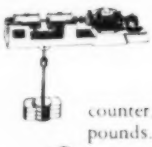

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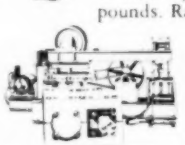

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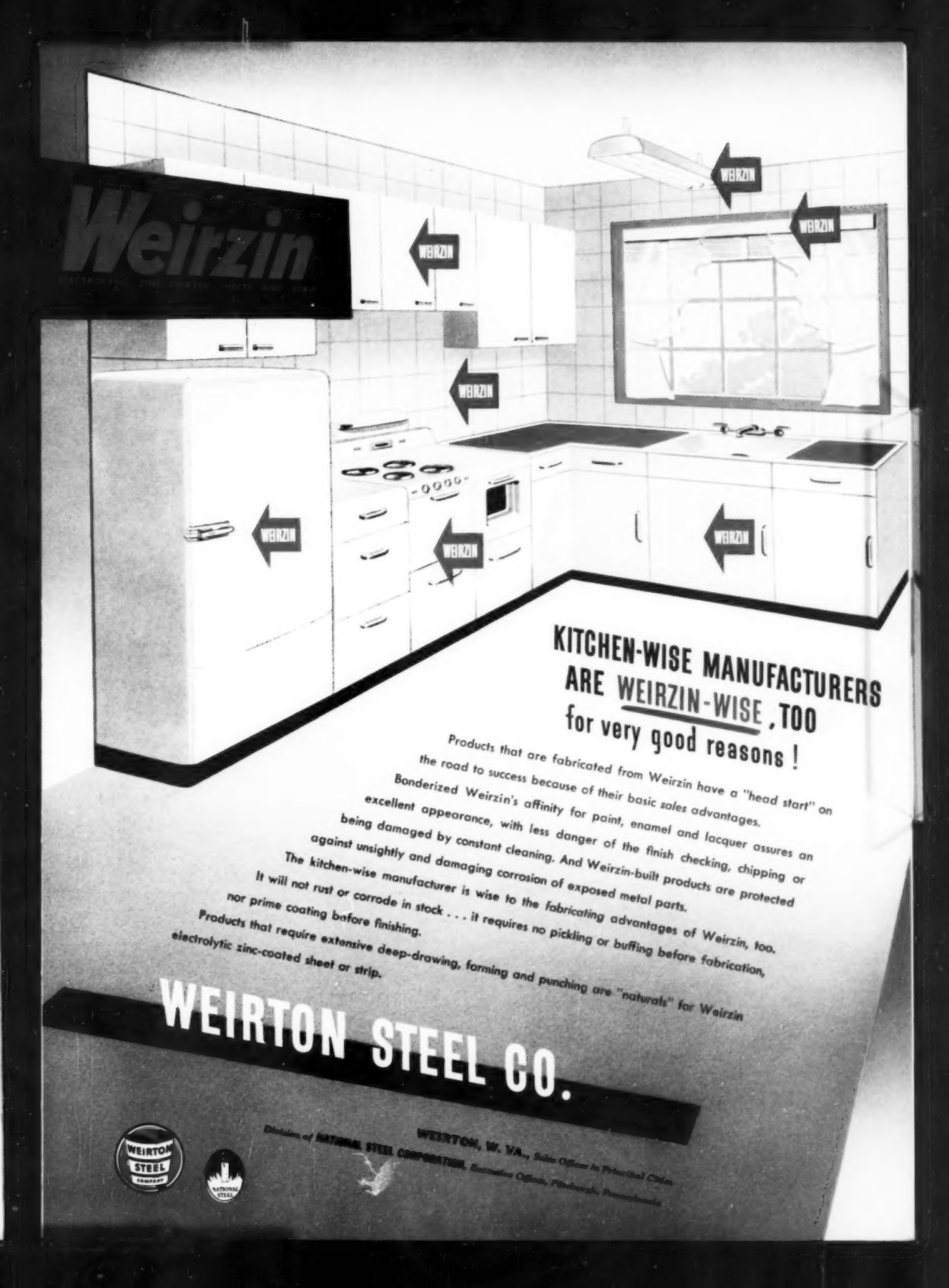

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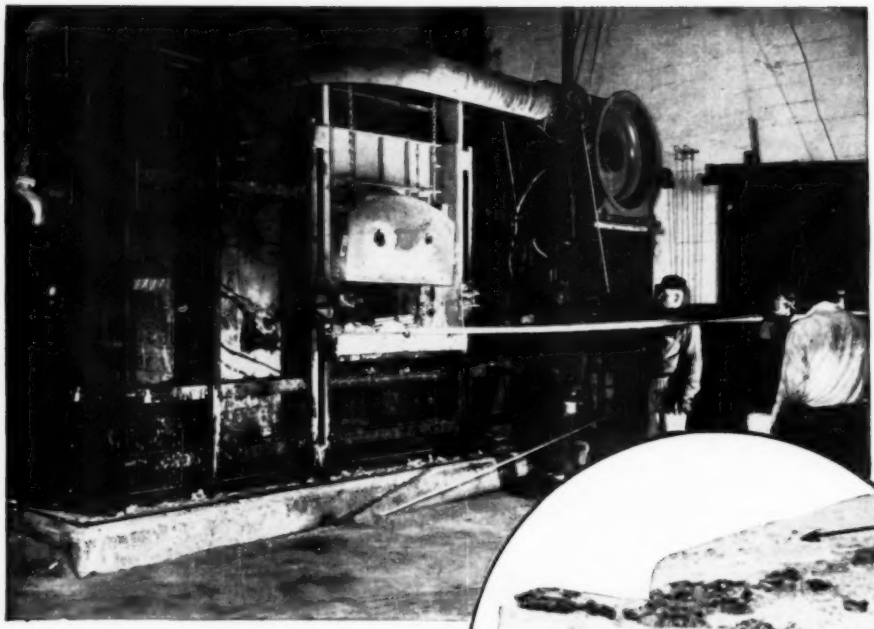

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If the energy absorption of the specimen receiving the embrittlement treatment was lower than that of the specimen not given this treatment, it was said that the steel was susceptible to temper brittleness. If the energy absorptions were the same, it was said that the steel was not susceptible. Several investigators found that plain carbon steels showed negligible difference in energy absorption in such tests (at least when the manganese content of the steel was below 0.60%), and concluded that plain carbon steels are not susceptible to temper brittleness.

Recently the deficiencies of the criterion mentioned above have been pointed out. The criterion now generally used for susceptibility to temper brittleness retains the heat treatments used in the earlier scheme, but instead of the notched-bar impact tests being made only at room temperature, they are made over a range of temperatures covering the transition from ductile to brittle fracture. If the transition temperature of the specimens receiving the embrittlement treatment is higher than those not given this treatment, the steel is considered susceptible to temper brittleness. If the transition temperatures of the two groups of specimens are the same, the steel is considered not susceptible. It has been reported that plain carbon steels showed negligible differ-

(Continued on p. 412)

*Abstracted from "Temper Brittleness of Plain Carbon Steels", by L. D. Jaffe and D. C. Buffum, *Metals Technology*, December 1948.

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TEMPER BRITTLENESS

(Continued from p. 410)

ence in transition temperature in such tests, and the earlier conclusion that these steels are not susceptible to temper brittleness was considered confirmed.

The lack of difference in transition temperature (and in energy absorption at room temperature) between specimens of plain carbon steel given an embrittling treatment and specimens not given an embrittling treatment may not, however, mean that temper brittleness does not develop in plain carbon steels. An alternative explanation is that temper brittleness develops so rapidly in plain carbon steels that even the specimens not given a deliberate embrittling treatment were unknowingly fully embrittled. This unintentional embrittlement might take place during the quench from the tempering temperature. If the specimens not given the embrittling treatment were nevertheless fully embrittled, they would behave in the notched-bar impact tests just like the companion specimens that were given the embrittling treatment.

According to the new hypothesis of the authors, in order to determine whether a plain carbon steel is temper brittle, its temperature of transition from ductile to brittle fracture may be compared with that of an alloy steel, with and without a treatment designed to develop temper brittleness. The old concept that plain carbon steels are not susceptible to temper brittleness then leads to the predictions:

1. Without the embrittlement treatment, the transition temperatures of the two steels are approximately the same.

2. With the embrittlement treatment, the transition temperature of the carbon steel is lower than that of the alloy steel.

The new hypothesis that plain carbon steels develop temper brittleness very rapidly (so rapidly that they become embrittled even when quenched from a high tempering temperature) leads to the predictions:

3. Without the deliberate embrittlement treatment, the transition temperature of the carbon steel is higher than that of the alloy steel.

4. With the embrittlement treat-

(Continued on p. 414)

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Here are the two largest continuous strip annealing lines in the world—provided in ultra-modern, electrically-heated vertical strip furnaces built by the Drever Company, of Philadelphia, Pa., for Carnegie-Illinois Steel Corporation's Vandergrift Plant.

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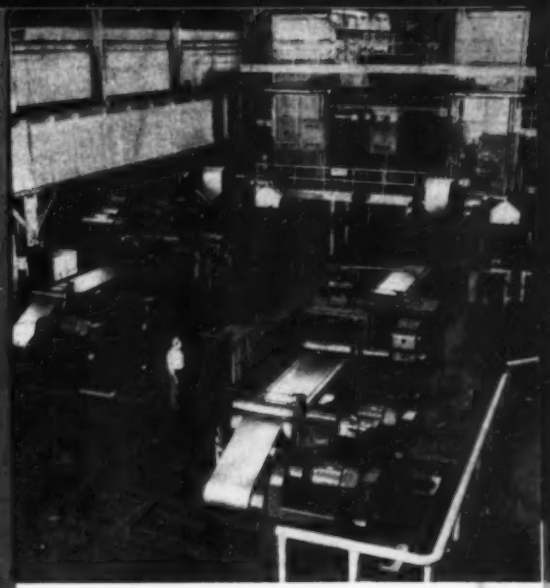
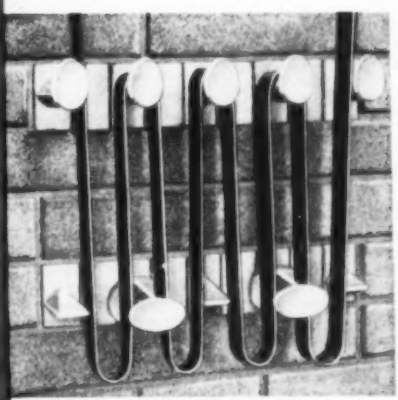
Nichrome is not only available as electrical resistor material for heating elements, but also in cast forms comprising a complete line of heat-treating equipment, from furnace ports to carburizing retorts and muffles. Send us your specifications. We'll gladly make recommendations.



The complete line of each of these Drever furnaces consists of two uncoilers for handling cold reduced coils; multiple seam welder; continuous strip cleaner; looping pit to secure accurate guiding and tensioning; 13 zone controlled-atmosphere annealing furnace, with cooling tower, drive bridle for forwarding strip; guided and controlled tensioning for recoiling; 2 recoilers.



Nichrome V Strip, 1½" wide x ⅛" thick, is looped as indicated to form heating elements.

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TEMPER BRITTLENESS

(Continued from p. 412)

ment, the transition temperatures of the two steels are approximately the same.

The carbon and alloy steels being compared should, of course, have similar microstructures. Since it is difficult to match microstructures of unhardened steels with respect to such factors as interlamellar spacing and the percentage of a proeutectoid constituent, comparison of tempered martensitic steels is preferable. If the carbon steel and the alloy steel consist of tempered martensite and are similar in hardness, carbon content, and austenitic grain size, the steels should be comparable. Also, the change in transition temperature produced by deliberate embrittlement treatments seems to be greater for a microstructure of tempered martensite than for other microstructures.

The authors have made an experimental test as outlined above, comparing 1045 and 3140 steels. The results of the test are in complete agreement with predictions (3) and (4), and in disagreement with predictions (1) and (2). The experimental work, therefore, supports the idea that plain carbon steels develop temper brittleness very rapidly, as opposed to the older view that plain carbon steels do not develop temper brittleness.

FERROMAGNETIC ALLOYS OF Mn*

MANGANESE remains one of the most puzzling elements known. The crystal structure changes three times between room temperature and the melting point (the transformation temperatures are 1250, 2010 and 2080° F., the melting point 2273° F.).

Manganese is paramagnetic, but becomes ferromagnetic when alloyed with any element of the nitrogen group. The authors examined the magnetic characteristics of the alloys of manganese with nitrogen, phosphorus, arsenic, antimony and bismuth. They state that ordinary commercial manganese does not alloy well with these elements, particularly with bismuth. In order to obtain alloys of a precise composition and free from impurities the authors built special equipment for the distillation (purification) of manganese and for alloying. Good sketches of the apparatus are given, but dimensions are not included. From 1 kg. of 97% Mn they were able to obtain 300 g. of pure metal, by distilling in a vacuum at a temperature of 2375° F.

Manganese was alloyed with arsenic in a pure alundum crucible placed inside a heavy iron crucible with the top welded on. After evacuation, an atmosphere of pure argon was introduced and the iron crucible was heated to 2375° F. by high-frequency induction. To make alloys with nitrogen the crucible was heated to about 1475° F. under a pressure of 200 kg. of pure nitrogen. The maximum amount absorbed

(Continued on p. 416)

*Abstracted from "Binary Ferromagnetic Manganese Alloys (Arsenides, Nitrides)", by Charles Gurtland and Jean Wyart, *Revue de Métallurgie*, August 1948, p. 271.

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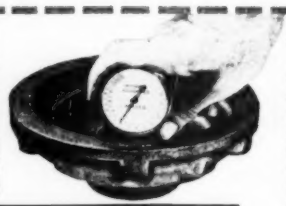

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FERROMAGNETIC ALLOYS OF Mn

(Continued from p. 414)

was 32 atomic %, indicating a compound Mn_2N.

The technique of the further procedure is not described and only the diagrammatic presentations of the results are given. With manganese-arsenic alloys, ferromagnetism starts with the Mn_2As compound and rises slowly until the composition Mn_3As_2 is reached. Next follows a region of mixed phases, Mn_3As_2 with Mn_4As_3, with a stronger rise in ferromagnetism. This is followed by another range of mixed structures up to 47% As, where a narrow range of a solid solution phase exists. This latter is most strongly ferromagnetic. Beyond 50% As the ferromagnetic characteristics decrease. The diagram worked out in this way was corroborated by X-ray diffraction studies. Certain ranges of alloys lost their ferromagnetism on heating as a result of a non-reversible transformation, others displayed a Curie point.

TESTING SOLDERED JOINTS*

THE SHEAR STRENGTH of a soldered joint depends on the shear strength of the solder, the adhesion of the solder to the base and the presence or absence of bending stresses during the test. A joint that is bent during a shear test may tear apart, altering the apparent shear strength.

The author suggests that the joint should be a double one, a heavier strip of the base metal being soldered between two thinner side pieces. This minimizes bending. The change from a single to a double joint had no effect on the shear strength of a solder with 25% Sn, a slight effect on a 40% Sn solder, and a considerable effect on a solder containing 98% Zn, 2% Cu. In soldering copper-covered aluminum, the zinc-base solder gave much stronger joints than the usual tin solders.

*Abstracted from "Shear Strength of Soldered Joints", by F. Trey, *Metallforschung*, Vol. 2, 1947, p. 84.

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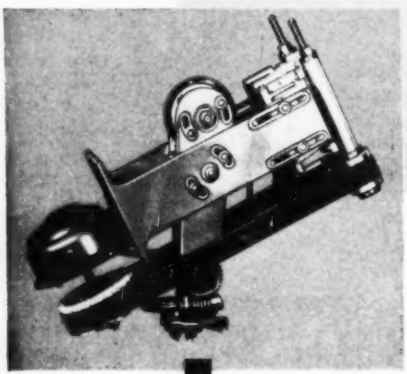

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Wall, in.	1/16	3/32	3/32	3/32	1/8	1/8	1/8	1/8	1/8

H-57930 Amber Rubber Tubing, Medium wall.

Bore, in.	1/8	3/16	1/4	5/16	3/8	1/2
Wall, in.	3/64	1/16	1/16	1/16	3/32	3/32

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Bore, in.	1/8	3/16	1/4	5/16	3/8	1/2
Wall, in.	1/16	3/32	3/32	3/32	1/8	1/8

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Bore, in.	3/16	1/4	5/16	3/8	1/2	
Wall, in.	3/64	1/16	1/16	3/32	3/32	

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Bore, in.	1/8	3/16	1/4	5/16	3/8	1/2	5/8	3/4	1
Wall, in.	1/16	3/32	3/32	3/32	1/8	1/8	1/8	1/8	1/8

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Wall, in.	3/64	1/16	1/16	3/32	3/32	

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Bore, in.	3/16	1/4	5/16	3/8	1/2	
Wall, in.	3/32	3/32	3/32	1/8	1/8	

H-58020 White Rubber Tubing, Medium wall.

Bore, in.	3/16	1/4	5/16	3/8	1/2	
Wall, in.	3/64	1/16	1/16	1/16	3/32	

H-58030 White Rubber Tubing, Heavy wall.

Bore, in.	1/8	3/16	1/4	5/16	3/8	1/2
Wall, in.	3/32	3/32	1/8	1/8	1/8	1/8

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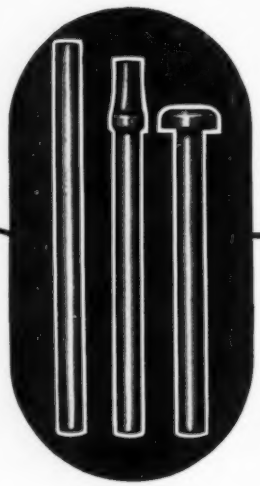

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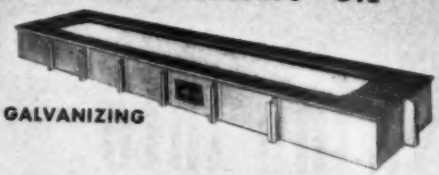

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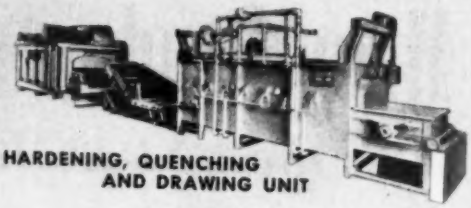

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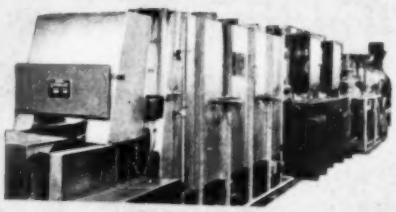

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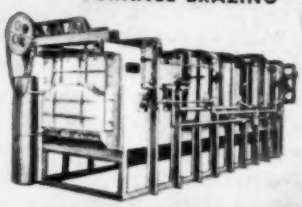

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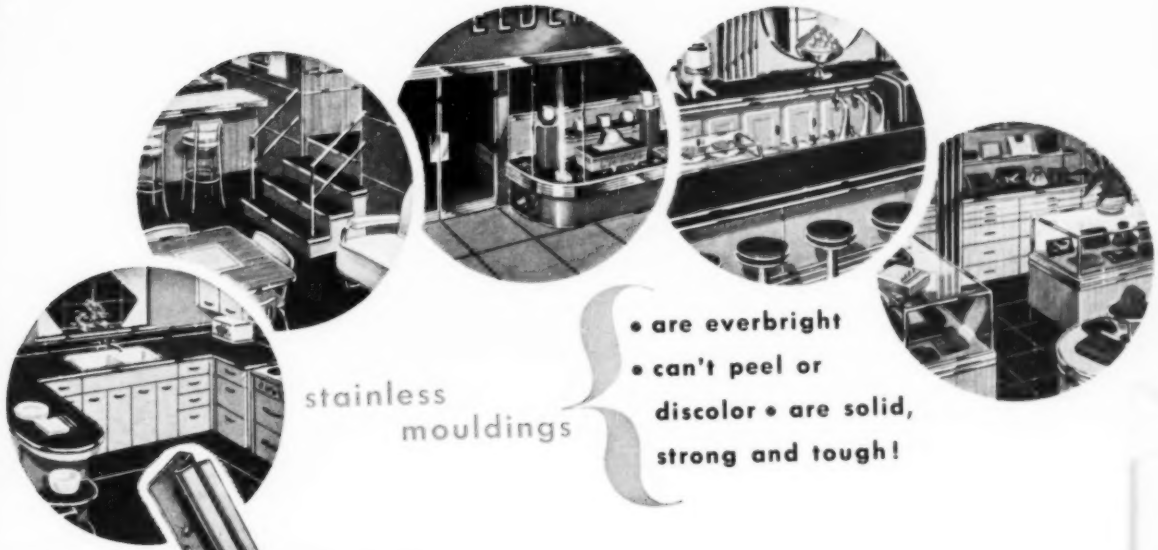

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- stainless mouldings fabricate better, deliver maximum consumer benefit, when you choose and use precision-made

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Because SUPERIOR Stainless Strip Steel handles more easily in mouldings manufacture, you enjoy an extra advantage . . . and easier handling is a built-in factor because we have the specialist's *know-how*. We produce only strip steels . . . to strictly-maintained standards of quality and precision in every grade, temper, dimension and finish . . . SUPERIOR through and through!

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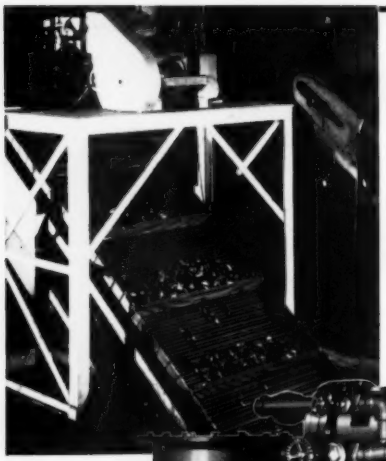

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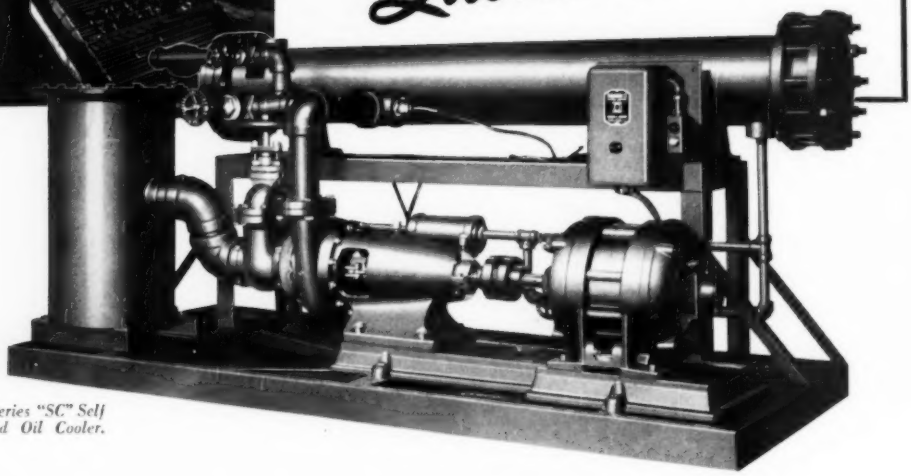
Because Uniformly Quenched!



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Correct oil quenching of heat-treated metals is a fine art which pays dividends in the *uniform quality* of the finished product. Quenching in an oil bath controlled by a B & G *Hydro-Flo* Oil Cooling System eliminates human error . . . reduces the process to a purely automatic operation, in which the final result can be calculated with mathematical certainty.

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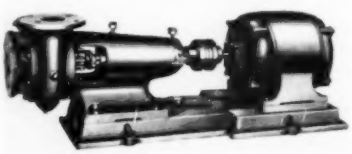

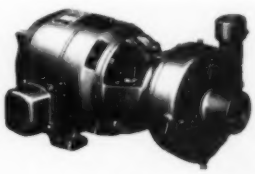

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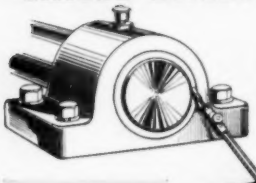

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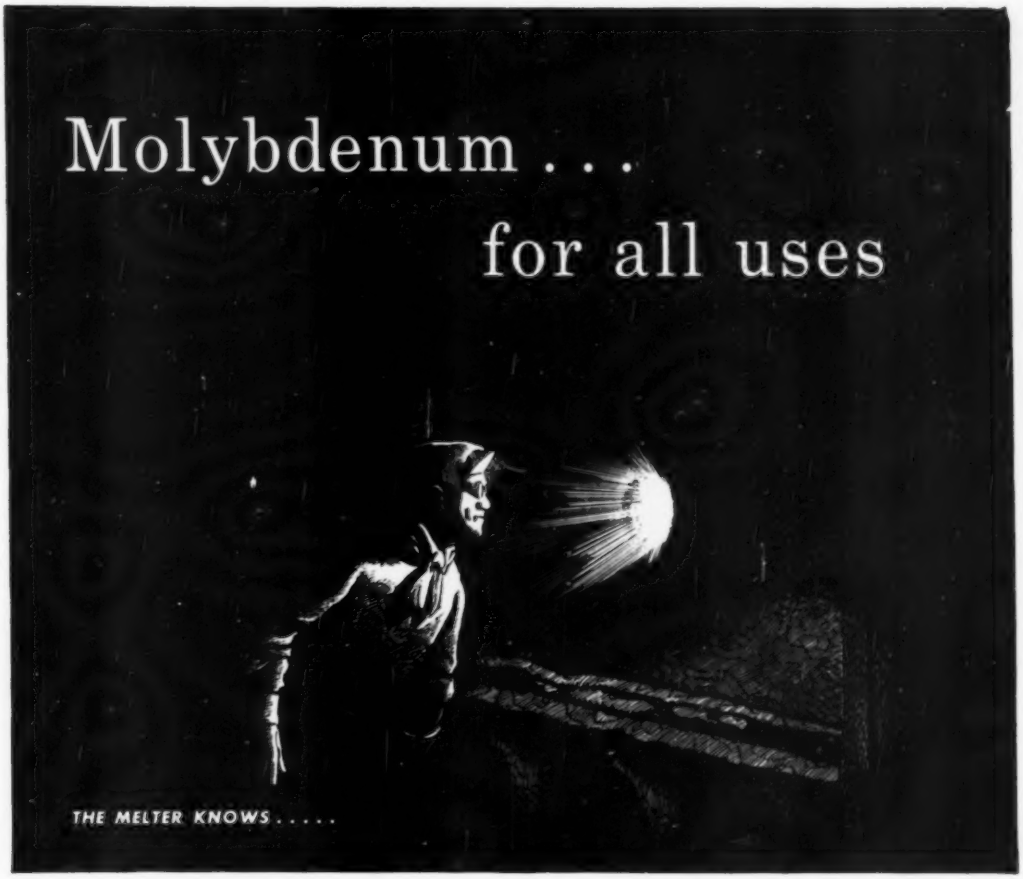

THE experienced melter knows he can depend on Molybdenum additions for uniform effects as calculated. He knows the customer can depend on the higher physical properties that Molybdenum adds. His comfortable assurance in the use of so trustworthy an agent is good to have. As a supplier of Molybdenum, Tungsten, and Boron, the Molybdenum Corporation is glad to be consulted at any time.

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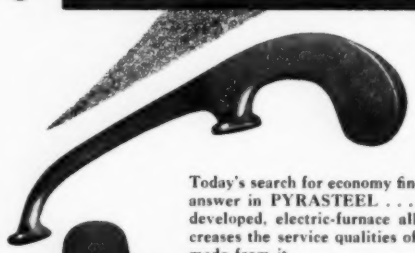

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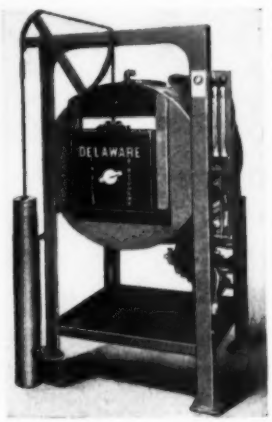

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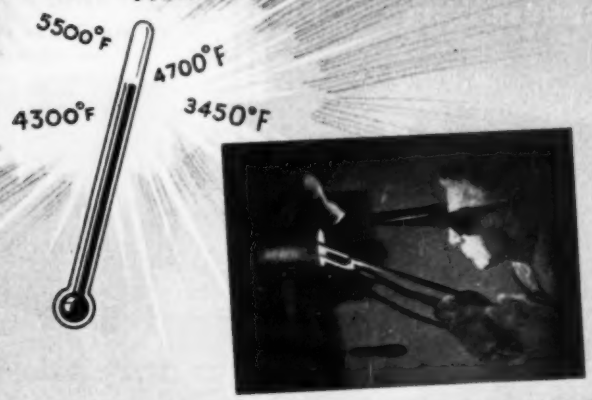

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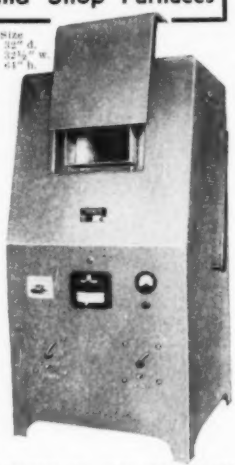

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PERECO also makes standard and special furnaces for any temperature from 450° to 2700° F.

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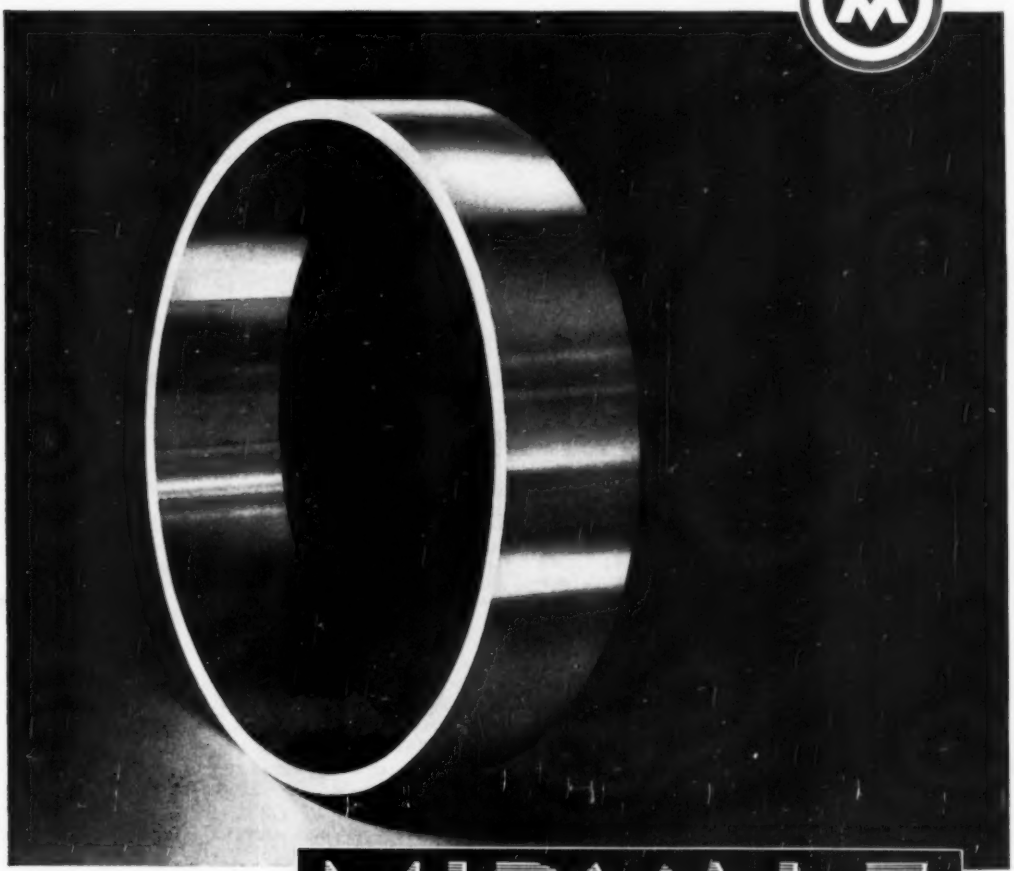

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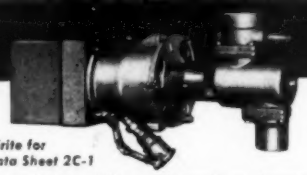

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They Laughed . .

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My friends knew I had no experience with magnesium.

They knew it was an untried metal where I was concerned.

So they laughed when I mentioned magnesium. They did not know I had just read that marvelous new book, "The Story of Magnesium". They didn't know. So—I told them about the book.

Here is a little book, I said, that's written for guys like you and me. Practical, down-to-earth stuff. Not scientific or technical. Not long hair. It packs into 258 pages, scarcely larger than pocket size, the story of magnesium's expansion from 7 tons a day to 300,000 tons a year during the war.

It's a book that tells the methods of making this metal from the rocks, brines and sea water, of the properties of the metal and of its alloys, and of the processes whereby metal in ingot form can be converted into washing machines, ladders, tools, vacuum sweepers and, maybe, even hairpins.

No one was laughing now. I told how this book is one of a series on self-education. How it discusses and illustrates equipment for alloying, melting and refining magnesium. I mentioned open-pot processes, the crucible process, scrap recovery, and so on.

Take castings now, I said. There are sand castings, and quite a few practices are involved, including heat treatment. Then there are permanent-mold castings and die castings.

There's an entire chapter on fabrication, which covers extrusion and rolling, forging, shallow and deep draws, spinning, hand forming and bending. Machining? There's a complete chapter on that, too, really complete.

And all this is the McCoy. It's written by an expert, name of W. H. Gross, who is with Dow Chemical Co., the big magnesium producer.

But I can't repeat the whole book to these guys. They should get a copy—it's not expensive—and read all about the various methods for riveting, welding and soldering, for cleaning, painting and decorative treatments. And uses! There's a 24-page chapter on a million different applications, more or less, that's worth the price of the book alone.

So, I say, get a copy of "The Story of Magnesium" for yourself. You'll *enjoy* reading this new kind of metals book—and its a good book to have handy. Just mail the coupon—

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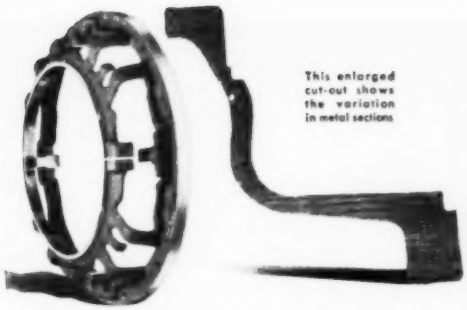
*With apologies, we believe, to the Alexander Hamilton Institute.



This enlarged cut-out shows the variation in metal sections

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This is a clutch cover plate that rotates at speeds up to 1,850 RPM—the heart of an improved fluid drive unit manufactured by the Twin Disc Clutch Company for the Allis Chalmers Corporation. Allis Chalmers uses the part in their HD-19 tractor—the largest track-laying tractor in the world.

When several other foundries attempted to produce this part, scrap loss exceeded 30%. Excessive shift, distortion, shrinkage and blowholes were often discovered *after the casting had been machined*. In spite of the high cost, Twin Disc engineers seriously considered redesigning the plate as a weldment.

Then Twin Disc brought us their problem. *We are now producing the plate at normal cost . . . with an abnormally low scrap loss percentage!*

If you have a casting problem, do as Twin Disc engineers did. Call on us.

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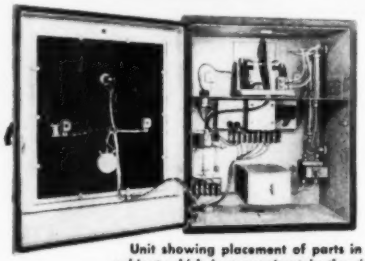

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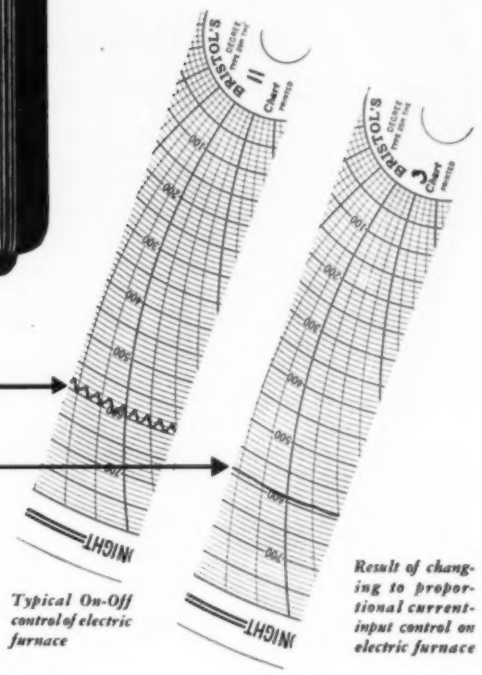

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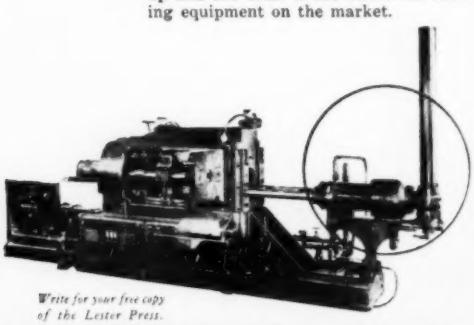

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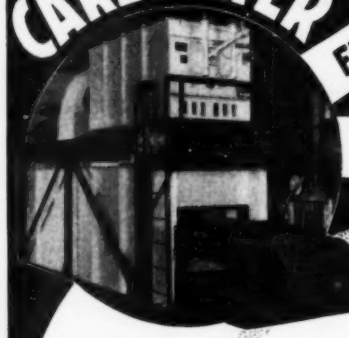

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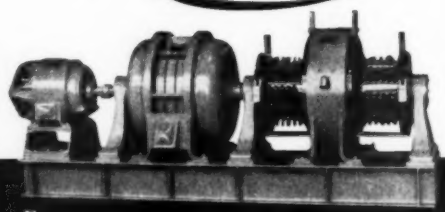

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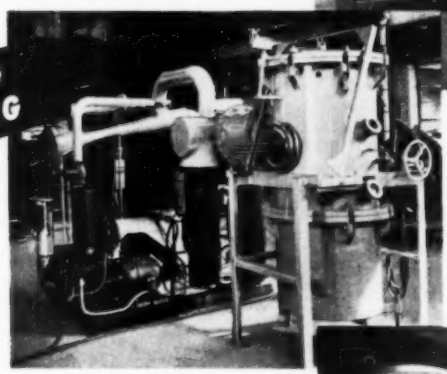

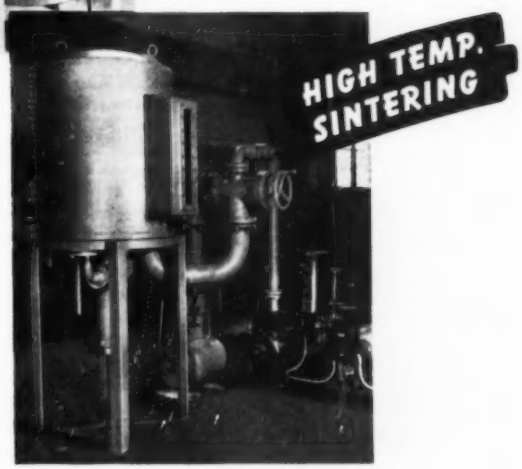

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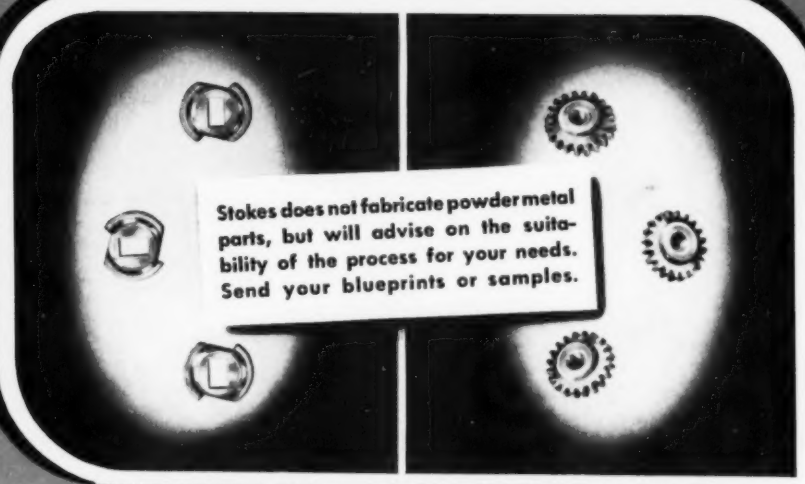
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